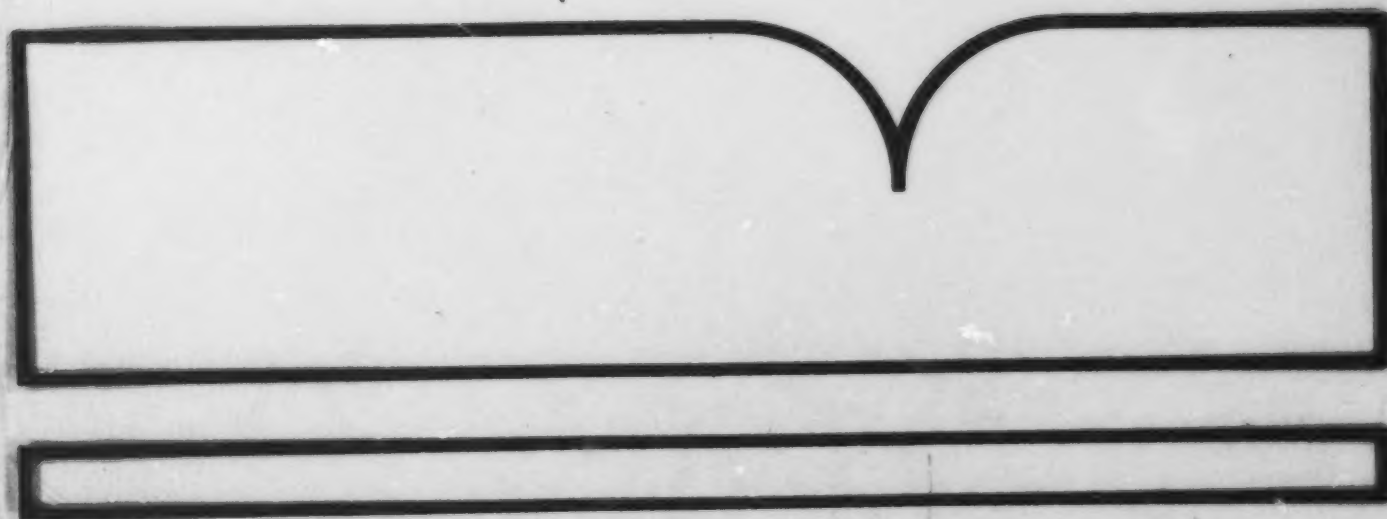


PB85-201267

Saltwater Wetlands for
Wastewater Management
Environmental Assessment

(U.S.) Environmental Protection Agency
Atlanta, GA

Nov 84



U.S. Department of Commerce
National Technical Information Service

NTIS

PB85-201267

United States
Environmental Protection
Agency

Region 4
345 Courtland Street, NE
Atlanta, GA 30365

EPA 904/10-84 128
November 1984



Saltwater Wetlands for Wastewater Management Environmental Assessment



REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

REPORT DOCUMENTATION PAGE	1. REPORT NO. EPA 904/10-84 128	2.	3. Recipient's Accession No. PR8 5 2012677AS
4. Title and Subtitle Saltwater Wetlands for Wastewater Management Environmental Assessment		5. Report Date November 1984	
7. Author(s) NEPA Compliance Section		6.	
9. Performing Organization Name and Address U.S. Environmental Protection Agency NEPA Compliance Section 345 Courtland St., N.E. Atlanta, Ga. 30365		8. Performing Organization Rept. No.	
12. Sponsoring Organization Name and Address		10. Project/Task/Work Unit No.	
		11. Contract(C) or Grant(G) No. (C) (G)	
15. Supplementary Notes		13. Type of Report & Period Covered	
		14.	
16. Abstract (Limit: 200 words) Saltwater wetlands have the potential for use as municipal and seafood processing wastewater-discharge sites. However, the potential also exists for adversely impacting these important natural resources. The Saltwater Wetlands for Wastewater Management Environmental Assessment is designed to explore the feasibility of using saltwater wetlands for municipal and seafood processing wastewater management and to identify areas of concern that are important to local, state and federal agencies in making wastewater management decisions affecting saltwater wetlands in the southeastern United States. This assessment is a companion study to the previously initiated Freshwater Wetlands for Wastewater Management Environmental Impact Statement (EIS). The emphasis of this Saltwater Wetlands Environmental Assessment is to provide a description of key saltwater wetland factors, disposal practices and options, regulatory considerations for disposal implementation, and areas where additional wetland research is needed.			
17. Document Analysis a. Descriptors b. Identifiers/Open-Ended Terms c. COSATI Field/Group			
18. Availability Statement	19. Security Class (This Report)	21. No. of Pages	
	20. Security Class (This Page)	22. Price	

SALTWATER WETLANDS
FOR
WASTEWATER MANAGEMENT
ENVIRONMENTAL ASSESSMENT

SEPTEMBER 1984

Prepared by
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IV - ATLANTA

With Assistance From
APPLIED BIOLOGY, INC.
GANNETT FLEMING CORDDRY AND CARPENTER, INC.

EXECUTIVE SUMMARY

Saltwater wetlands have the potential for use as municipal and seafood processing wastewater-discharge sites. However, the potential also exists for adversely impacting these important natural resources. The Saltwater Wetlands for Wastewater Management Environmental Assessment is designed to explore the feasibility of using saltwater wetlands for municipal and seafood processing wastewater management and to identify areas of concern that are important to local, state and federal agencies in making wastewater management decisions affecting saltwater wetlands in the southeastern United States. This assessment is a companion study to the previously initiated Freshwater Wetlands for Wastewater Management Environmental Impact Statement (EIS).

The emphasis of this Saltwater Wetlands Environmental Assessment is to provide a description of key saltwater wetland factors, disposal practices and options, regulatory considerations for disposal implementation, and areas where additional wetland research is needed.

WETLANDS DEFINITION AND INVENTORY

There are various definitions applied to wetlands by federal agencies and the USEPA Region IV states. The U.S. Fish and Wildlife Service classification, developed for the National Wetlands Inventory, relies on vegetation, hydrology and soil indicators for characterizing wetlands. It is currently the most comprehensive wetland classification system available. The system addresses different user needs by providing dif-

ferent levels of detail, offers regional consistency and recognizes significant ecological differences among wetland types. The FWS classification is gradually being adopted for use by most regulatory agencies.

Mapping efforts in the six Region IV coastal states were inventoried. Figures were used to depict the status of the FWS National Wetlands Inventory as of October 1983.

EXISTING SALTWATER-WETLAND DISCHARGES

An information survey program was conducted to identify and characterize existing saltwater-wetland discharges in the USEPA Region IV coastal states. The majority of those responding to the survey indicated that they discharged into brackish waters, mostly into tidal creeks. None stated that they discharged directly onto saltwater wetlands. During site visits, wastewater discharges into tidal creeks were observed on several occasions. Marsh vegetation at the mouth of or bordering these creeks appeared taller and denser at one site but, for the most part, did not appear to differ from adjacent areas that are less likely to be influenced by the discharge.

INSTITUTIONAL CONSIDERATIONS

A large part of federal institutional involvement pertaining to wastewater discharges in saltwater wetlands stems from the Clean Water Act. Regulatory programs established through the Act that are administered by EPA are the National Pollutant Discharge Elimination System Permit Program, the 201 Construction Grants Program and the Water Quality

Standards Program. The Dredge and Fill Permit Program is administered by the Corps of Engineers. Two other federal programs, Fish and Wildlife Coordination (which involves the Fish and Wildlife Service and National Marine Fisheries Service) and the National Shellfish Sanitation Program administered by the Public Health Service, involve advisory duties when a proposed water resource development activity could adversely impact fish, wildlife or shellfish of a given water body.

State programs or procedures which impact the feasibility of discharging wastewater to saltwater wetlands are presented. These programs and procedures include water quality classifications and standards, discharge permits and methodology for determining wasteload allocations for wetlands, the process for prioritizing projects for 201 Construction Grant Program funding, and various state coastal area management and protection plans. Procedural and regulatory variations among the states when dealing with saltwater wetlands are also addressed. These differences are significant in permitting activities in saltwater wetlands within the states and along state boundaries or interstate waters.

Key institutional issues related to wastewater management in saltwater wetlands include the following:

- . Lack of wetland definition and lack of specificity in defining state waters and landward extent of classified water areas.
- . Inappropriate water quality criteria applied to wetlands.
- . Lack of procedures for establishing effluent limits.

SCIENTIFIC CONSIDERATIONS

Components of saltwater wetland ecosystems include geomorphology, vegetation, hydrology, water quality and wildlife. Biotic and abiotic factors operate in dynamic equilibrium and the characteristics, functions and processes of saltwater wetlands are variable and interrelated. Disposal of municipal or seafood-processing wastewater has the potential of disrupting the integrity of these wetlands. However, the potential for positive effects must also be considered.

Five major factors were found to be important when evaluating wastewater discharge alternatives in saltwater wetlands. These factors are:

- Erosion would be expected to vary with characteristics of the soil, density of vegetation and effluent rates per unit of marsh surface area.
- Nutrients may affect the marsh vegetation and/or the estuary. The types or amounts of nutrients entering the marsh would depend on the characteristics of the effluent, while their pathways in the marsh would depend on such factors as sediment characteristics, uptake rates by vegetation and frequency of tidal inundation.
- Toxic substances and pathogens entering the marsh will also vary according to the quality of the effluent. This factor is particularly relevant for consideration because of public health implications.
- Vegetation may be affected by several parameters associated with wastewater disposal including decreased salinity, continual soil saturation and nutrient loading. A primary concern is that shifts in plant species composition or distribution may occur in the marsh.
- Wildlife may be affected if shifts in the vegetation occur that alter food availability, nesting sites, cover or similar habitat parameters. Wildlife could also be affected by toxic substances introduced with treated effluent. The occurrence of threatened and endangered animal species is another reason for wildlife to be a factor for consideration.

ENGINEERING CONSIDERATIONS

The engineering issues associated with discharging municipal and seafood processing wastewater to a saltwater wetland are related primarily to maintaining wetland function and ecology while promoting nutrient removal. Key engineering factors discussed include the following:

- . Selection of a suitable saltwater wetland site for wastewater discharge;
- . Development of hydrologic and nutrient loading criteria to determine detention times and discharge schedules;
- . Wastewater discharge system design to determine water depths, back-up systems, disinfection techniques, etc.;
- . Construction methods to install equipment without permanently disturbing the wetland ecosystem;
- . Operation and maintenance options to insure that discharge amounts, discharge frequency and flow paths are maintained after system start-up;
- . Monitoring and compliance issues to include the definition of monitoring parameters, sampling techniques and monitoring schedules to meet permit conditions and requirements.

KEY FACTORS

Key scientific and engineering factors for evaluating saltwater wetlands as potential wastewater disposal sites are geology, hydrology and water quality. The key institutional factor is regulatory control. These key factors are:

- . Regulatory control refers to permitting (including effluent limits), enforcement of water quality standards and funding. Regulatory requirements may promote or restrict the use of saltwater wetlands for wastewater discharge.
- . Hydrological components refer to the effluent volume and rate(s) of application, as well as to tidal fluctuations, water table level, seasonal precipitation, runoff and other natural factors.

- Water quality components refer to the constituency of the effluent and to potential changes in water quality parameters following discharge.
- Geological components refer to composition of the sediments, particularly as they relate to porosity (permeability) and movement of water or wastewater into or through the sediments.

AREAS FOR FURTHER STUDY

The use of saltwater wetlands for the management of municipal or seafood processing wastewater is an area in which many technical questions remain unanswered. Areas for further study and some representative issues are presented.

- Soils/geomorphology: The rate of nutrient uptake by soils and length of time that pathogens remain viable in sediments are not quantified.
- Vegetation: Specific effects of freshwater wastewater discharge on saltwater wetland vegetation and the ability of natural salt marsh vegetation to remove nutrients are not known.
- Hydrology: Hydrologic loading rates suitable to saltwater wetland maintenance and effects of discharges on seasonal wet/dry cycles are not well understood. The effects of seasonal and tidal influences as well as periodic coastal storms on wetland water quality in wetland wastewater systems are not known.
- Wildlife: Specific impacts on shellfish and other aquatic and terrestrial fauna from the discharge of toxins, metals and pathogens have not been quantified.
- Engineering: Acceptable loading rates, wastewater detention times, water depths and effects of chlorine or other disinfectants on the wetland food chain and public health require further study.

TABLE OF CONTENTS

	<u>Page</u>
EXECUTIVE SUMMARY -----	ii
TABLE OF CONTENTS -----	viii
LIST OF TABLES -----	xi
LIST OF FIGURES -----	xiv
1.0 INTRODUCTION -----	1-1
1.1 Background and Purpose -----	1-1
1.2 Areas of Special Concern -----	1-2
1.3 Approach and Objectives -----	1-3
2.0 WETLANDS DEFINITION AND INVENTORY -----	2-1
2.1 Wetlands Definition and Classification -----	2-1
2.1.1 Marine Classification System -----	2-8
2.1.2 Estuarine Classification System -----	2-9
2.1.3 Classification Comparisons -----	2-10
2.2 Wetland Inventories in Region IV -----	2-10
2.2.1 North Carolina -----	2-13
2.2.2 South Carolina -----	2-13
2.2.3 Georgia -----	2-17
2.2.4 Florida -----	2-21
2.2.5 Alabama -----	2-23
2.2.6 Mississippi -----	2-28
2.3 Summary -----	2-28
2.4 Literature Cited -----	2-31
3.0 PROFILE OF EXISTING SALTWATER-WETLAND DISCHARGES -----	3-1
3.1 North Carolina -----	3-6
3.2 South Carolina -----	3-10
3.3 Georgia -----	3-12
3.4 Florida -----	3-14
3.5 Alabama -----	3-14
3.6 Mississippi -----	3-15
3.7 Summary -----	3-17
4.0 INSTITUTIONAL CONSIDERATIONS -----	4-1
4.1 Federal Programs -----	4-2
4.1.1 Water Quality Standards Program -----	4-2
4.1.2 National Pollutant Discharge Elimination System (NPDES) Permit Program -----	4-7
4.1.3 201 Construction Grants Program -----	4-11
4.1.4 Corps of Engineers Permit Program -----	4-16
4.1.5 Fish and Wildlife Coordination -----	4-21
4.1.6 National Shellfish Sanitation Program -----	4-24

TABLE OF CONTENTS
(continued)

	<u>Page</u>
4.2 State Programs -----	4-26
4.2.1 Alabama -----	4-26
4.2.2 Florida -----	4-29
4.2.3 Georgia -----	4-34
4.2.4 Mississippi -----	4-36
4.2.5 North Carolina -----	4-39
4.2.6 South Carolina -----	4-44
4.3 Major Institutional Issues -----	4-48
4.3.1 Need for Clear Direction in Wetlands Wastewater Management -----	4-48
4.3.2 Need to Clarify Regulatory Definitions -----	4-49
4.3.3 Need for Program Specific Guidance -----	4-51
4.4 Literature Cited -----	4-57
5.0 SCIENTIFIC CONSIDERATIONS -----	5-1
5.1 Geomorphology -----	5-2
5.1.1 Estuaries -----	5-2
5.1.2 Salt Marsh Ontogeny -----	5-7
5.1.3 Soils -----	5-8
5.1.4 Assessment -----	5-16
5.2 Vegetation -----	5-20
5.2.1 Marshes -----	5-21
5.2.2 Mangrove Swamps -----	5-29
5.2.3 Aquatic Grassbeds -----	5-31
5.2.4 Intertidal Flats -----	5-33
5.2.5 Summary -----	5-33
5.3 Hydrology -----	5-34
5.3.1 Regional Characterization -----	5-36
5.3.2 Hydrologic Budgeting -----	5-38
5.3.3 Inundation -----	5-44
5.3.4 Buffering -----	5-48
5.3.5 Storage -----	5-48
5.3.6 Hydraulic Loading -----	5-49
5.3.7 Impacts from Wastewater Effluent Application -----	5-49
5.4 Water Quality -----	5-50
5.4.1 General Water Quality Parameters -----	5-51
5.4.2 Nutrient Removal and Metal Uptake -----	5-58
5.4.3 Assessment -----	5-69
5.5 Wildlife -----	5-73
5.5.1 Fish and Shellfish -----	5-76
5.5.2 Birds -----	5-77
5.5.3 Reptiles and Amphibians -----	5-82
5.5.4 Mammals -----	5-83
5.5.5 Threatened and Endangered Wildlife Species -	5-85
5.5.6 Impacts to Wildlife from Wastewater Application -----	5-102

TABLE OF CONTENTS
(continued)

	<u>Page</u>
5.6 Scientific Factors Related to Wastewater Management in Saltwater Wetlands -----	5-105
5.6.1 Erosion -----	5-106
5.6.2 Nutrients -----	5-107
5.6.3 Toxic Substances -----	5-108
5.6.4 Vegetation -----	5-108
5.6.5 Wildlife -----	5-109
5.7 Literature Cited -----	5-111
6.0 ENGINEERING CONSIDERATIONS -----	6-1
6.1 Management of Municipal Wastewaters Utilizing Saltwater Wetlands -----	6-2
6.1.1 Planning and Preliminary Design -----	6-10
6.1.2 Design of Municipal Systems -----	6-20
6.1.3 Installation and Operation-Maintenance-Repair -----	6-29
6.1.4 Monitoring -----	6-33
6.2 Management of Seafood-Processing Wastewaters Utilizing Saltwater Wetlands -----	6-35
6.2.1 Planning and Preliminary Design -----	6-36
6.2.2 Design and Installation -----	6-48
6.2.3 Operation, Maintenance, Repair and Monitoring -----	6-52
6.3 Engineering-Related Issues and Options -----	6-52
6.4 Literature Cited -----	6-56
7.0 SUMMARY OF INSTITUTIONAL, SCIENTIFIC AND ENGINEERING CONSIDERATIONS -----	7-1
7.1 Institutional Considerations -----	7-1
7.1.1 Federal Involvement -----	7-1
7.1.2 State Involvement -----	7-3
7.2 Scientific Considerations -----	7-6
7.3 Engineering Considerations -----	7-7
7.4 Key Factors -----	7-7
7.5 Study Recommendations -----	7-11
7.5.1 Soils/Geomorphology -----	7-12
7.5.2 Vegetation -----	7-12
7.5.3 Hydrology -----	7-12
7.5.4 Water Quality -----	7-13
7.5.5 Wildlife -----	7-13
7.5.6 Engineering -----	7-13
8.0 LIST OF PREPARERS -----	8-1

LIST OF TABLES

	<u>Page</u>
Table 2.1-1 Marine and Estuarine Systems with Classes, Subclasses, and Selected Dominance Types -----	2-3
Table 2.1-2 A Comparison of the Wetland Classification Systems Presented in the U.S. Fish and Wildlife Service Circular Δ39 and the U.S. Fish and Wildlife Service Classification of Wetlands and Deepwater Habitats -----	2-11
Table 2.2-1 Wetland Inventories in North Carolina -----	2-14
Table 2.2-2 Wetland Inventories in South Carolina -----	2-16
Table 2.2-3 Wetland Inventories in Georgia -----	2-19
Table 2.2-4 Wetland Inventories in Florida -----	2-22
Table 2.2-5 Wetland Inventories in Alabama -----	2-25
Table 2.2-6 Wetland Inventories in Mississippi -----	2-29
Table 3.0-1 U.S. Environmental Protection Agency, Region IV, Saltwater Wetlands for Wastewater Management EIA, Wetlands Discharge Survey -----	3-2
Table 3.0-2 Number of Saltwater-Wetland Discharges Surveyed by State and the Number of Respondents -----	3-5
Table 3.1-1 Profile of Saltwater Wetland Discharges in USEPA Region IV Based on Survey Responses -----	3-8
Table 4.1-1 Agencies and Water Use Classifications for EPA Region IV Coastal States -----	4-6
Table 4.1-2 Corps of Engineers Permit Evaluation Criteria -----	4-18
Table 4.1-3 Summary of EPA Criteria for Approval of Dredged or Fill Material Discharge Under Section 404(b)(1) of the CWA -----	4-20
Table 4.1-4 National Marine Fisheries Service Guidelines for Assessing Wetland Alteration -----	4-23
Table 5.1-1 Relative Mobilities of Selected Metals in Aquatic Systems -----	5-17

LIST OF TABLES
(continued)

	<u>Page</u>
Table 5.5-1 North Carolina's Protected Species Associated with Saltwater Wetlands -----	5-89
Table 5.5-2 South Carolina's Protected Species Associated with Saltwater Wetlands -----	5-90
Table 5.5-3 Georgia's Protected Species Associated with Saltwater Wetlands -----	5-93
Table 5.5-4 Florida's Protected Species Associated with Saltwater Wetlands -----	5-94
Table 5.5-5 Alabama's Protected Species Associated with Saltwater Wetlands -----	5-99
Table 5.5-6 Mississippi's Protected Species Associated with Saltwater Wetlands -----	5-101
Table 6.1-1 Quality Guidelines, Marine Water Quality and Typical Effluent Quality for Selected Constituents -----	6-3
Table 6.1-2 Projected Effluent Quality for Ocean Discharge and Approximate Marine Water Quality -----	6-4
Table 6.1-3 Potential Impacts of Wastewater on Wetland Ecosystems -----	6-7
Table 6.1-4 Potential Adverse Effects of Certain Wastewater Constituents -----	6-8
Table 6.1-5 Physical and Chemical Pollutant Removal Mechanisms in Wetland and Aquatic Systems -----	6-15
Table 6.1-6 Collection of Site-Specific Data for Evaluation of a Wetland for Wastewater Treatment -----	6-18
Table 6.1-7 Effluent Application Configurations -----	6-22
Table 6.1-8 Summary of Example Wastewater Disposal Capital Costs -----	6-25
Table 6.1-9 Design Guide and Checklist for Wetland- Wastewater Systems -----	6-30
Table 6.2-1 Characteristics of Various Types of Seafood Processing -----	6-40

LIST OF TABLES
(continued)

	<u>Page</u>
Table 6.2-2 Analysis of Selected Packing House and Processing Plant Effluents in the Vicinity of Brunswick, GA During July-August 1979 -----	6-43
Table 6.2-3 Descriptions of Physical-Chemical Treatment Processes Utilized to Treat Seafood Processing Wastewaters -----	6-46
Table 6.2-4 Technology Assessment for the Seafood Processing Industry in the Contiguous U.S. -----	6-47
Table 6.2-5 Design Parameters for Types of Seafood Processing Wastewater Treatment -----	6-50
Table 6.3-1 Engineering-Related Issues and Options for Saltwater Wetlands -----	6-54
Table 7.3-1 Engineering Factors Pertinent to Utilizing Wetlands for Any Type of Wastewater Management -----	7-8
Table 7.3-2 Engineering Factors Pertinent to Utilizing Wetlands for Seafood-Processing Wastewater Management -----	7-10

LIST OF FIGURES

	<u>Page</u>
Figure 2.2-1 Hierarchial Classification of Wetlands and Deepwater Habitats of the Marine and Estuarine Systems -----	2-5
Figure 2.1-2 Diagrammatic Description of the Marine System habitats -----	2-6
Figure 2.1-3 Diagrammatic Description of the Estuarine system habitats -----	2-7
Figure 2.2-1 Status of the National Wetlands Inventory in North Carolina -----	2-15
Figure 2.2-2 Status of the National Wetlands Inventory in South Carolina -----	2-18
Figure 2.2-3 Status of the National Wetlands Inventory in Georgia -----	2-20
Figure 2.2-4 Status of the National Wetlands Inventory in Florida -----	2-24
Figure 2.2-5 Status of the National Wetlands Inventory in Alabama -----	2-27
Figure 2.2-6 Status of the National Wetlands Inventory in Mississippi -----	2-30
Figure 5.1-1 Development Stages in a Shoreline of Submergence -----	5-3
Figure 5.1-2 Generalized Well-Developed Estuarine System -----	5-4
Figure 5.1-3 Schematic Representation of Estuarine Dynamics Showing River Flow Moving Obliquely Towards the Viewer, Tidal Inlet Flow Moving Obliquely away from the Viewer During Flood Tide, and Lateral Distribution Processes Acting to Disperse Sediment Throughout the Basin -----	5-5
Figure 5.1-4 Development of a Typical New England Salt Marsh with Rising Sea Level and Continued Sedimentation -----	5-9
Figure 5.1-5 A Model of the Marsh Nitrogen (N) Cycle Showing the Major Stores of N and Interrelated Processes -----	5-11
Figure 5.1-6 Phosphorus Cycle in a Salt Marsh -----	5-12

LIST OF FIGURES
(continued)

	<u>Page</u>
Figure 5.3-1 Coastal Energy Levels -----	5-37
Figure 5.3-2 Wetland Water Movement during Tidal Cycle -----	5-47
Figure 5.5-1 The Estuarine Ecosystem of Coastal Alabama and Representative Energy Symbols -----	5-75
Figure 5.5-2 Common Food Relationships -----	5-78
Figure 5.5-3 Generalized Trophic Relationships of Representative Birds of Estuarine Emergent Wetlands -----	5-80
Figure 6.2-1 Typical Steps Involved in Preparing Seafood for Market -----	6-37
Figure 6.2-2 Typical Shrimp Processing Schematic -----	6-39

1.0 INTRODUCTION

Saltwater wetlands have the potential for use as wastewater-disposal sites. However, the potential also exists for adversely impacting these important natural resources. This assessment is designed to explore the feasibility and acceptability of using saltwater wetlands for municipal and seafood processing wastewater management and to identify areas of concern that are important to local, state and federal agencies in making wastewater management decisions affecting saltwater wetlands in the southeastern United States. The emphasis of this assessment is in providing a description of key saltwater wetland factors, discharge practices and options, and regulatory considerations for discharge implementation.

1.1 BACKGROUND AND PURPOSE

The Saltwater Wetlands for Wastewater Management Environmental Assessment (Saltwater Wetlands Assessment) was initiated in response to inquiries and concerns expressed by agencies, states and individuals who were aware of the potential for wastewater management in saltwater wetlands and who requested an examination of the issue.

Much of the future growth in the U.S. is projected to occur in the Southeast and will ultimately affect coastal areas. Many small coastal communities are experiencing or will experience an increase in wastewater discharged from municipal treatment plants because of seasonal population increases caused by vacationers and/or seafood processing wastewaters from facilities operating in summer and early fall. The growth of small coastal communities is likely to result in the loss of biologically productive and commercially valuable saltwater wetlands. The use of these wetlands for wastewater management, when adverse impacts can be avoided

or minimized, could allow for the alleviation of the potential problem of insufficient suitable wastewater discharge sites and use of wetlands in such a way that they will be preserved. However, care must be exercised to assure that the use and function of these wetlands are not impacted by wastewater discharges.

The purpose of the Saltwater Wetlands Environmental Assessment is, thus, to examine the institutional, scientific and engineering issues that are important in considering the use of saltwater wetlands in the southeastern U.S. for the disposal of treated municipal wastewater and seafood-processing wastewater and to identify areas for further study.

This is a generic study that includes the U.S. Environmental Protection Agency (EPA) Region IV's six coastal states: North Carolina, South Carolina, Georgia, Florida, Alabama and Mississippi. The present assessment is a companion study to the previously initiated Freshwater Wetlands for Wastewater Management EIS.

1.2 AREAS OF SPECIAL CONCERN

The use of saltwater wetlands to receive treated wastewater may provide a discharge alternative that could offer significant environmental advantages, including discharge options in areas that lack a suitable receiving stream and wetland preservation. Many questions, however, arise when the potential impacts of wetland discharges are considered. Areas of special concern include:

- . The quality and quantity of effluent entering wetlands,
- . Specific effluent characteristics or other circumstances which would preclude the discharge of wastewater to saltwater wetlands,
- . Presence of threatened or endangered species in wetlands,
- . Impacts of effluent of various qualities and volumes on floral and faunal communities and species,
- . Hydrologic consequences of wetland discharges,
- . Seasonal variations in wetland characteristics,
- . Maintenance of current water-quality standards and wastewater-treatment requirements while utilizing wetlands for wastewater management,
- . Potential beneficial results of a wetlands discharge, particularly to artificially depleted wetlands,
- . Institutional constraints or prohibitions on wetlands discharge alternatives at federal, state or local levels,
- . Differentiation of wetland types, identifying those more or less appropriate for wetlands discharges,
- . Impacts to recreational or commercial resources,
- . Impacts to wetland function,
- . Salinity impacts,
- . Food chain impacts,
- . Available analytical monitoring techniques, and
- . Financial impacts related to use of a wetlands as compared to other alternative discharges.

1.3 APPROACH AND OBJECTIVES

This report provides an identification of the issues and needs of current technical and institutional aspects associated with saltwater-wetland discharges. The emphasis in this effort is in providing a description of key saltwater wetland factors, disposal practices and

options, and federal, state and local implementation practices and options. Special objectives of this assessment include:

- . Inventory and describe existing wetland discharges,
- . Conduct a regional survey to identify existing technical and institutional considerations associated with saltwater-wetland discharges,
- . Identify key wastewater parameters and key wetland factors critical to maintaining beneficial wetland functions and uses,
- . Identify key institutional factors to be considered in the regulation of wetlands used for wastewater management, and
- . Identify technical areas for which additional study is recommended.

2.0 WETLANDS DEFINITION AND INVENTORY

There are various definitions applied to wetlands by federal agencies and the Region IV states. These definitions are based on soils, hydrology and/or vegetation. A purpose of this chapter is to establish the system of definitions used in the Saltwater Wetlands Environmental Assessment and correlate this system with other existing definitions. Another component of this chapter is an inventory of currently mapped saltwater wetlands and the status of such mapping activities.

2.1 WETLANDS DEFINITION AND CLASSIFICATION

Several definitions and classification schemes have been applied to wetlands. Among the federal agencies, the Corps of Engineers (COE) and the Fish and Wildlife Service (FWS) have developed comprehensive classification systems, with that recently developed by the FWS being the most comprehensive to date. The FWS wetland classification system was developed by Cowardin et al. (1979) for the National Wetlands Inventory. It provides several different levels of detail in the classification of a wetland and, therefore, addresses different user needs. This system relies on vegetation, hydrology and soil indicators to characterize wetland types.

The FWS classification system was selected for use in the Freshwater Wetlands EIS (EPA, 1983) and its use will continue in the Saltwater Wetlands Assessment. The FWS system was chosen because of its regional consistency and because it recognized significant ecological differences among wetland types (EPA, 1983). The FWS classification system is gradually being adopted for use by most regulatory agencies, which further supports its use in the present assessment.

The FWS classification was intended 1) to define ecological units having certain natural attributes in common; 2) to arrange these units in a system for the purpose of resource management; 3) to supply units for wetland inventory and mapping and 4) to provide consistency in concepts and terminology throughout the United States (Cowardin et al., 1979). These authors defined wetlands as "lands that are transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water."

The FWS classification system is a hierarchical series proceeding from the system level (e.g., marine, riverine) to the subsystem (e.g., subtidal), class (e.g., unconsolidated bottom), subclass (e.g., organic) and dominance type levels (e.g., clam worm, Nereis succinea). Modifiers for water regimes (e.g., subtidal), water chemistry types (e.g., mixohaline) and soils (e.g., acid) are used for class, subclass and dominance type descriptions. Special modifiers (e.g., partly drained) are also used to relate manmade alterations in wetlands and deepwater habitats.

Cowardin et al. (1979) have reviewed five systems in the FWS classification: Marine, Estuarine, Riverine, Lacustrine and Palustrine. Only the Marine and Estuarine Systems are relevant to the Saltwater Wetlands Assessment (Table 2.1-1; Figures 2.1-1 through 2.1-3). Classes which may contain elements pertinent to this EIS are indicated by brackets in Table 2.1-1. The heavy lines used in Figure 2.1-1 show those classes which are pertinent to this EIS.

TABLE 2.1-1

MARINE AND ESTUARINE SYSTEMS WITH CLASSES, SUBCLASSES,
AND SELECTED DOMINANCE TYPES (EXCERPTED FROM COWARDIN ET AL., 1979)*

System, Class, and Subclass	Examples of Dominance Types
MARINE	
Rock Bottom	
Bedrock	American lobster (<u>Homarus americanus</u>)
Rubble	Encrusting sponge (<u>Hippospongia gossypina</u>)
Unconsolidated Bottom	
Cobble-Gravel	Brittle star (<u>Amphipholis squamata</u>)
Sand	Great Alaskan tellin (<u>Tellina lutea</u>)
Mud	Atlantic deep-sea scallop (<u>Placopecten magellanicus</u>)
Organic	Clam worm (<u>Nereis succinea</u>)
Aquatic Bed	
Rooted Vascular	Turtle grass (<u>Thalassia testudinum</u>)
Algal	Kelp (<u>Macrocystis pyrifera</u>)
Reef	
Coral	Coral (<u>Porites porites</u>)
Worm	Reef worm (<u>Sabellaria cementarium</u>)
Rocky Shore	
Bedrock	Gooseneck barnacle (<u>Pollicipes polymerus</u>)
Rubble	California mussel (<u>Mytilus californianus</u>)
Unconsolidated Shore	
Cobble-Gravel	Acorn barnacle (<u>Balanus balanoides</u>)
Sand	Pismo clam (<u>Tivela stultorum</u>)
Mud	Boring clam (<u>Platyodon cancellatus</u>)
Organic	False angel wing (<u>Petricola pholadiformis</u>)
ESTUARINE	
Rock Bottom	
Bedrock	Sea whip (<u>Muricea californica</u>)
Rubble	Tunicate (<u>Cnemidocarpa finmarkiensis</u>)
Unconsolidated Bottom	
Cobble-Gravel	Smooth Washington clam (<u>Saxidomus giganteus</u>)
Sand	Sand dollar (<u>Dendraster excentricus</u>)
Mud	Baltic macoma (<u>Macoma balthica</u>)
Organic	Soft-shell clam (<u>Mya arenaria</u>)
Aquatic bed	
Algal	Rockweed (<u>Fucus vesiculosus</u>)
Rooted Vascular	Eelgrass (<u>Zostera marina</u>)
Floating	Water hyacinth (<u>Eichhornia crassipes</u>)
Reef	
Mollusk	Eastern oyster (<u>Crassostrea virginica</u>)
Worm	Reef worm (<u>Sabellaria floridensis</u>)

TABLE 2.1-1
(continued)
MARINE AND ESTUARINE SYSTEMS WITH CLASSES, SUBCLASSES,
AND SELECTED DOMINANCE TYPES (EXCERPTED FROM COWARDIN ET AL., 1979)*

System, Class, and Subclass	Examples of Dominance Types
Streambed	
Cobble-Gravel	Blue mussel (<u>Mytilus edulis</u>)
Sand	Red ghost shrimp (<u>Callinassa californiensis</u>)
Mud	Mud snail (<u>Nassarius obsoletus</u>)
Organic	Ribbed mussel (<u>Modiolus demissus</u>)
Rocky Shore	
Bedrock	Acorn barnacle (<u>Chthamalus fragilis</u>)
Rubble	Plate limpet (<u>Acmaea testudinalis</u>)
[Unconsolidated Shore	
Cobble-Gravel	Blue mussel (<u>Mytilus edulis</u>)
Sand	Quahog (<u>Mercenaria mercenaria</u>)
Mud	Clam worm (<u>Nereis succinea</u>)
Organic	Fiddler crab (<u>Uca pugnax</u>)
[Emergent Wetland	
Persistent	Saltmarsh cordgrass (<u>Spartina alterniflora</u>)
Nonpersistent	Samphire (<u>Salicornia europea</u>)
[Scrub-Shrub Wetland	
Needle-leaved Evergreen	Sitka spruce (<u>Picea sitchensis</u>)
Broad-leaved Evergreen	Mangrove (<u>Conocarpus erectus</u>)
Needle-leaved Deciduous	Bald cypress (<u>Taxodium distichum</u>)
Broad-leaved Deciduous	Marsh elder (<u>Iva frutescens</u>)
Dead	None
[Forested Wetland	
Needle-leaved Evergreen	Sitka spruce (<u>Picea sitchensis</u>)
Broad-leaved Evergreen	Red mangrove (<u>Rhizophora mangle</u>)
Needle-leaved Deciduous	Bald cypress (<u>Taxodium distichum</u>)
Broad-leaved Deciduous	Red ash (<u>Fraxinus pennsylvanica</u>)
Dead	None

*The Riverine, Lacustrine and Palustrine Systems have been deleted. Classes which may be pertinent to this study are indicated by brackets.

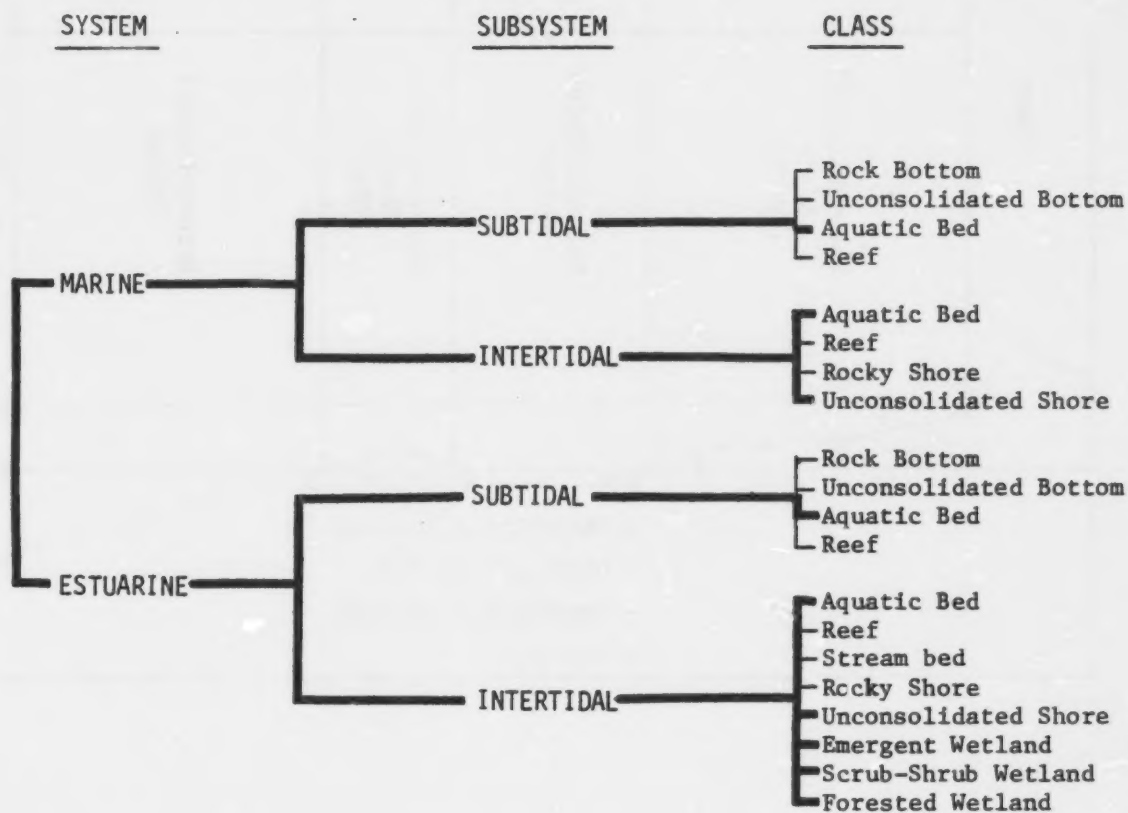


Figure 2.1-1. Hierarchical classification of wetlands and deepwater habitats of the Marine and Estuarine Systems. (Source: excerpted from Cowardin, et al., 1979 with the Rivertine, Lacustrine and Palustrine Systems deleted, classes pertinent to this study are highlighted by dark line).

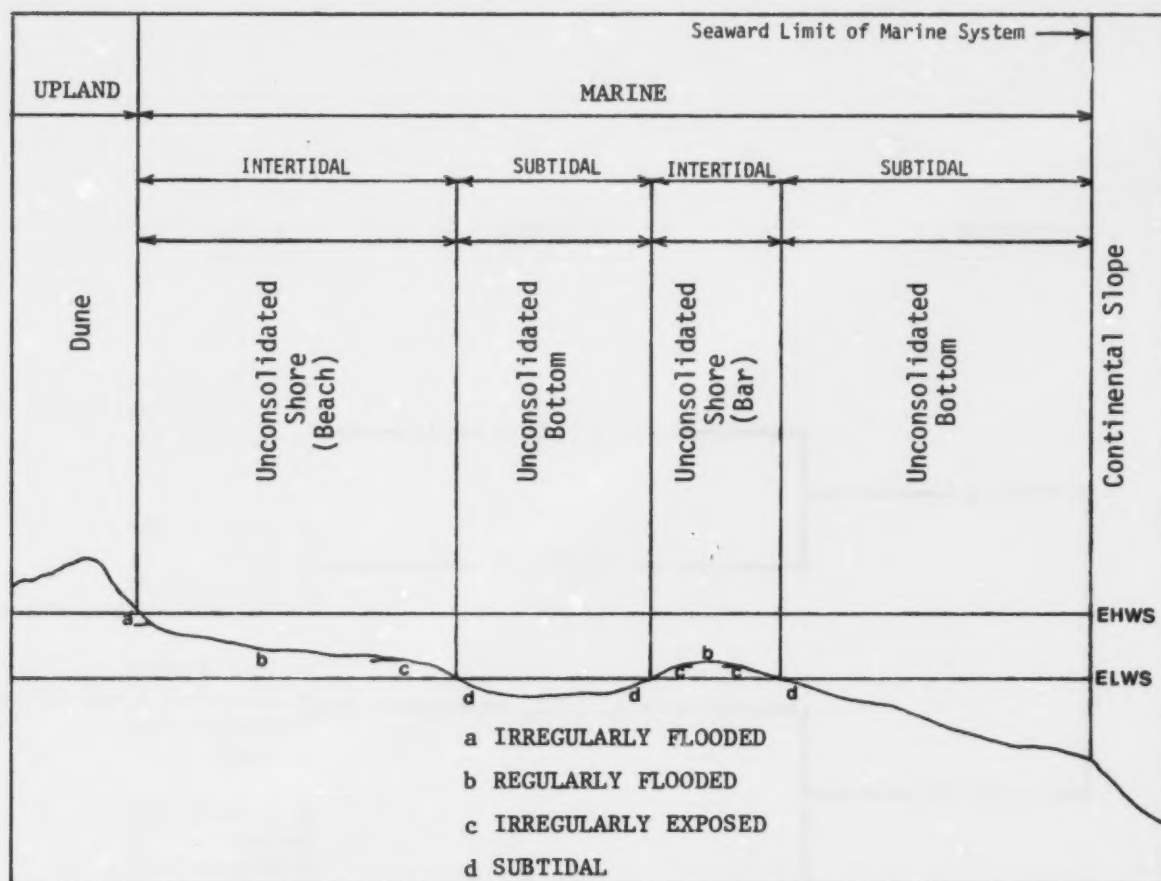


Figure 2.1-2. Diagrammatic description of the Marine System habitats. Note: "EHWS = extreme high water of spring tides; ELWS = extreme low water of spring tides." (Source: excerpted from Cowardin, et al., 1979).

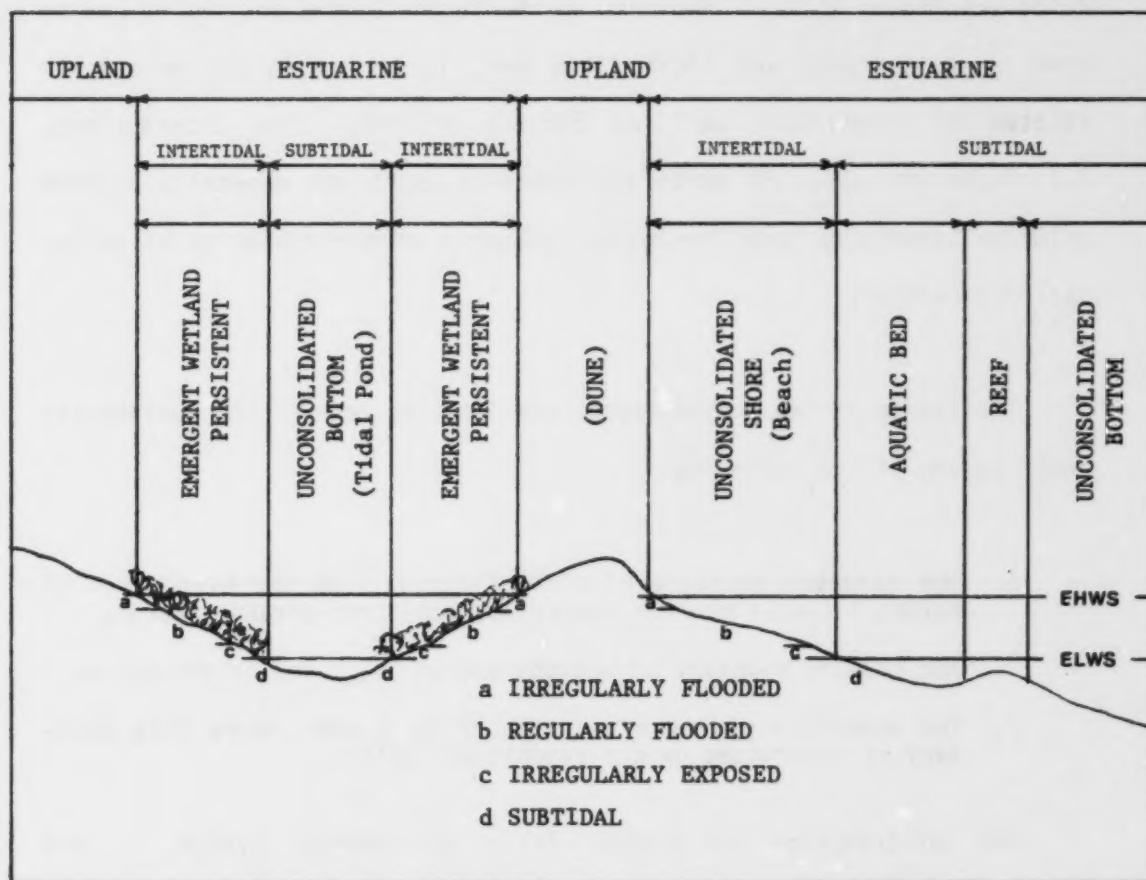


Figure 2.1-3. Diagrammatic description of the Estuarine System habitats. Note: "EHWS = extreme high water of spring tides; ELWS = extreme low water of spring tides." (Source: excerpted from Cowardin, et al., 1979).

2.1.1 Marine Classification System

The FWS classification defines the Marine System as "the open ocean overlying the continental shelf and its associated high energy coastline" (also see Figure 2.1-2). Habitats in the Marine System are influenced by open ocean currents and tidal flows and, in an ecological sense, are related to traditional wetlands because of tidal flow interactions. Salinities are above 30 parts per thousand (ppt) and generally without dilution other than some freshwater influence at the mouths of estuaries and from rainfall.

The limits of the Marine System are from the edge of the continental shelf to one of the following:

1. The landward boundary of tidal flooding (extreme high water of spring tides) including the splash zone from breaking waves;
2. The seaward boundary of wetland emergents, trees or shrubs; or
3. The seaward boundary of the Estuarine System, where this boundary is determined by non-vegetation factors.

The distribution of biota within the Marine System in the southeastern U.S. is influenced by wave exposure, substrate texture and physiochemical composition, tidal amplitude, site latitude relative to temperature, and solar radiation.

The two subsystems of the Marine System are the subtidal and intertidal. The subtidal subsystem pertains to substrate that is always submerged while the intertidal subsystem refers to substrate that is exposed and flooded by the tide and includes the shoreline splash zone.

2.1.2 Estuarine Classification System

The Estuarine System "consists of deepwater tidal habitats and adjacent tidal wetlands that are usually semienclosed by land but have open, partly obstructed, or sporadic access to the open ocean, and in which ocean water is at least occasionally diluted by freshwater runoff from the land" (Cowardin et al., 1979; also see Figure 2.1-3). Salinities may be above open ocean levels periodically because of evaporation, but may also be diluted along low energy coastlines.

The Estuarine System extends to one of three boundaries:

1. Upstream and landward to where ocean salinities are less than 0.5 ppt during average annual low flow;
2. To an imaginary line drawn to enclose the mouth of a river, bay or sound; and
3. To the seaward boundary of wetland emergents, shrubs or trees if not included above in Item 2.

In addition, offshore areas that are "of continuously diluted seawater" are also part of the Estuarine System.

The Estuarine System is described as a low-energy (wave action) system that includes both estuaries and lagoons, and is more strongly affected by land than is the Marine System. Oceanic tides, freshwater runoff, precipitation, evaporation and wind influence estuarine water chemistry and water regimes. Salinities are hyperhaline (>40 ppt), euhaline (30.0-40 ppt) or mixohaline (0.5-30 ppt). The latter includes polyhaline (18.0-30 ppt), mesohaline (5.0-18 ppt) and oligohaline (0.5-5 ppt). Estuarine salinities can be variable or fairly stable. As in the

case of the Marine System, the Estuarine System subsystems are either subtidal or intertidal.

2.1.3 Classification Comparisons

Several wetland classification systems devised within the scientific and regulatory communities are reviewed in the Freshwater Wetlands EIS (EPA, 1983). The most frequently used wetland classification system in the U.S. was FWS Circular #39 (Shaw and Fredine, 1956) that replaced an earlier classification by Martin et al. (1953). Circular #39 delineates wetlands into 20 different types based on vegetation and hydrology. Because of the widespread use of Circular #39 since 1956, a significant amount of state and federal legislation is tied to its definitions and classification (EPA, 1983). Although the trend is presently toward adopting the more detailed FWS classification developed for the National Wetlands Inventory (Cowardin et al., 1979), continued use of Circular #39 warrants a comparison of the two classification systems. Comparisons relevant to saltwater wetlands are presented in Table 2.1-2.

2.2 WETLAND INVENTORIES IN REGION IV

Coastal wetland classification and mapping projects have been done by a variety of state and federal agencies. The FWS National Wetlands Inventory is the most comprehensive mapping effort in Region IV, but this current inventory has been preceded by other national inventories (EPA, 1983). The figures accompanying each of the following sections illustrate the status of the FWS inventory as of October 1983.

TABLE 2.1-2

A COMPARISON OF THE WETLAND CLASSIFICATION SYSTEMS PRESENTED IN THE
U.S. FISH AND WILDLIFE SERVICE CIRCULAR #39 AND THE
U.S. FISH AND WILDLIFE SERVICE CLASSIFICATION OF WETLANDS AND DEEPWATER HABITATS
(EXCERPTED FROM COMARDIN ET AL., 1979, INCLUDING REFERENCES:
NON-SALTWATER WETLAND INFORMATION DELETED)

Circular #39 type and references for examples of typical vegetation	Classification of Wetlands and Deepwater Habitats		
	Classes	Water regimes	Salinity
Type 12-coastal shallow fresh marshes Marsh (Anderson et al. 1968) Estuarine bay marshes, estuarine river marshes (Stewart 1962) Fresh and intermediate marshes (Chabreck 1972)	Emergent Wetland	Regularly Flooded Irregularly Flooded Semipermanently Flooded- Tidal	Mixohaline Fresh Fresh
Type 13-Coastal deep fresh marshes Marsh (Anderson et al. 1968) Estuarine bay marshes, estuarine river marshes (Stewart 1962) Fresh and intermediate marshes (Chabreck 1972)	Emergent Wetland	Regularly Flooded Semipermanently Flooded- Tidal	Mixohaline Fresh
Type 14-Coastal open fresh water Estuarine bays (Stewart 1962)	Aquatic Bed Unconsolidated Bottom	Subtidal Permanently Flooded- Tidal	Mixohaline Fresh
Type 15-Coastal salt flats Panne, slough marsh (Redfield 1972) Marsh pans (Pestrong 1965)	Unconsolidated Shore	Regularly Flooded Irregularly Flooded	Hyperhaline Euhaline
Type 16-Coastal salt meadows Salt marsh (Redfield 1972; Chapman 1974)	Emergent Wetland	Irregularly Flooded	Euhaline Mixohaline

TABLE 2.1-2
(continued)
A COMPARISON OF THE WETLAND CLASSIFICATION SYSTEMS PRESENTED IN THE
U.S. FISH AND WILDLIFE SERVICE CIRCULAR #39 AND THE
U.S. FISH AND WILDLIFE SERVICE CLASSIFICATION OF WETLANDS AND DEEPWATER HABITATS
(EXCERPTED FROM COWARDIN ET AL., 1979, INCLUDING REFERENCES:
NON-SALTWATER WETLAND INFORMATION DELETED)

Circular #39 type and references for examples of typical vegetation	Classification of Wetlands and Deepwater Habitats		
	Classes	Water regimes	Salinity
Type 17-Irregularly flooded salt Marshes Salt marsh (Chapman 1974) Saline, brackish, and inter- mediate marsh (Eleuterius 1972)	Emergent Wetland	Irregularly Flooded	Euhaline Mixohaline
Type 18-Regularly flooded salt marshes Salt marsh (Chapman 1974)	Emergent Wetland	Regularly Flooded	Euhaline Mixohaline
Type 19-Sounds and bays Kelp beds, temperate grass flats (Phillips 1974) Tropical marine meadows (Odum 1974) Eelgrass beds (Akins and Jefferson 1973; Eleuterius 1973)	Unconsolidated Bottom Aquatic Bed Flat	Subtidal Irregularly Exposed Regularly Flooded Irregularly Flooded	Euhaline Mixohaline Euhaline Mixohaline
Type 20-Mangrove swamps Mangrove swamps (Walsh 1974) Mangrove swamp systems (Kunezler 1974) Mangrove (Chapman 1976)	Scrub-Shrub Wetland Forested Wetland	Irregularly Exposed Regularly Flooded Irregularly Flooded	Hyperhaline Euhaline Mixohaline Fresh

2.2.1 North Carolina

Early coastal-wetlands mapping effort in North Carolina was completed for 41 coastal plain counties in 1962 using the wetlands classification system of FWS Circular #39 (Table 2.2-1). This project was intended for wildlife management purposes and produced maps at 1:250,000 scale. In 1976 mapping of 20 coastal counties was performed that described coastal wetlands in a single tidal-marshland category. Maps at a scale of 1:24,000 were produced.

Smaller mapping projects were undertaken in 1982 including 1:24,000 scale mapping of the peninsula between Pamlico and Albermarle Sounds. This EPA sponsored mapping was in response to significant agricultural clearing and development in wetland areas. Scattered mapping efforts (Figure 2.2-1) by the U.S. Fish and Wildlife Service as part of the National Wetlands Inventory include work in the Currituck Sound area and work in progress in the Pamlico/Albermarle Peninsula. Much of the FWS mapping in North Carolina is in the planning stages at this point, but the entire coastal plain eventually will be mapped as part of the National Wetlands Inventory.

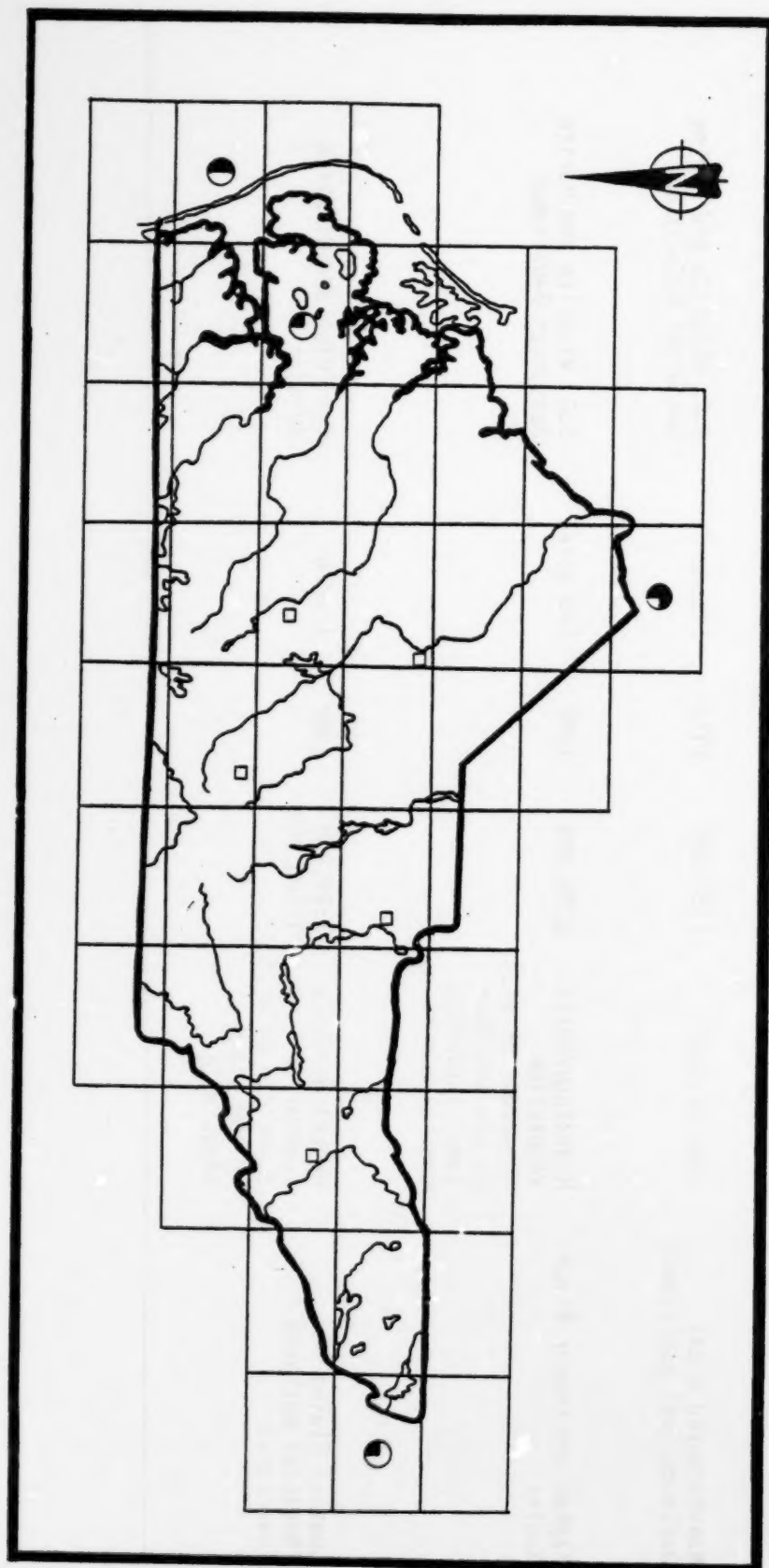
2.2.2 South Carolina

In 1976 all non-forested tidal wetlands were mapped at 1:24,000 scale by the South Carolina Wildlife and Marine Resources Department (SCWMRD) but were never formally published (Table 2.2-2). Maps at scales of 1:24,000 and 1:100,000 have been made for all of the coastal wetlands in South Carolina by the U.S. Fish and Wildlife Service as part of the

TABLE 2.2-1

WETLAND INVENTORIES IN NORTH CAROLINA

Inventory coverage	Classification	Scale	Date	Resolution	Agency
Coastal Plains of N.C. (41 counties)	Vegetational (FWS Circular #39)	1:250,000	1962	40 acres	N.C. Office of Coastal Management
Currituck Sound (National Wetlands Inventory)	Hydrology/Soils/ Vegetation (Cowardin et al.) to the subclass and water regime level	1:24,000	1982	1 acre	U.S. Fish and Wildlife Service
Peninsula between Albemarle and Pamlico Sounds	Vegetational	1:24,000	1982	1 acre	U.S. Environmental Protection Agency



LEGEND
SEPTEMBER 1983

- IN PROGRESS
- LARGE SCALE DRAFT OVERLAYS OR MAPS AVAILABLE
- LARGE SCALE FINAL OVERLAYS OR MAPS AVAILABLE
- SMALL SCALE AND LARGE SCALE MAPS AVAILABLE
- SMALL SCALE MAPS ONLY

Figure 2.2-1. Status of the National Wetlands Inventory in North Carolina.
Source: U.S. Fish and Wildlife Service. October 1983.

TABLE 2.2-2

WETLAND INVENTORIES IN SOUTH CAROLINA

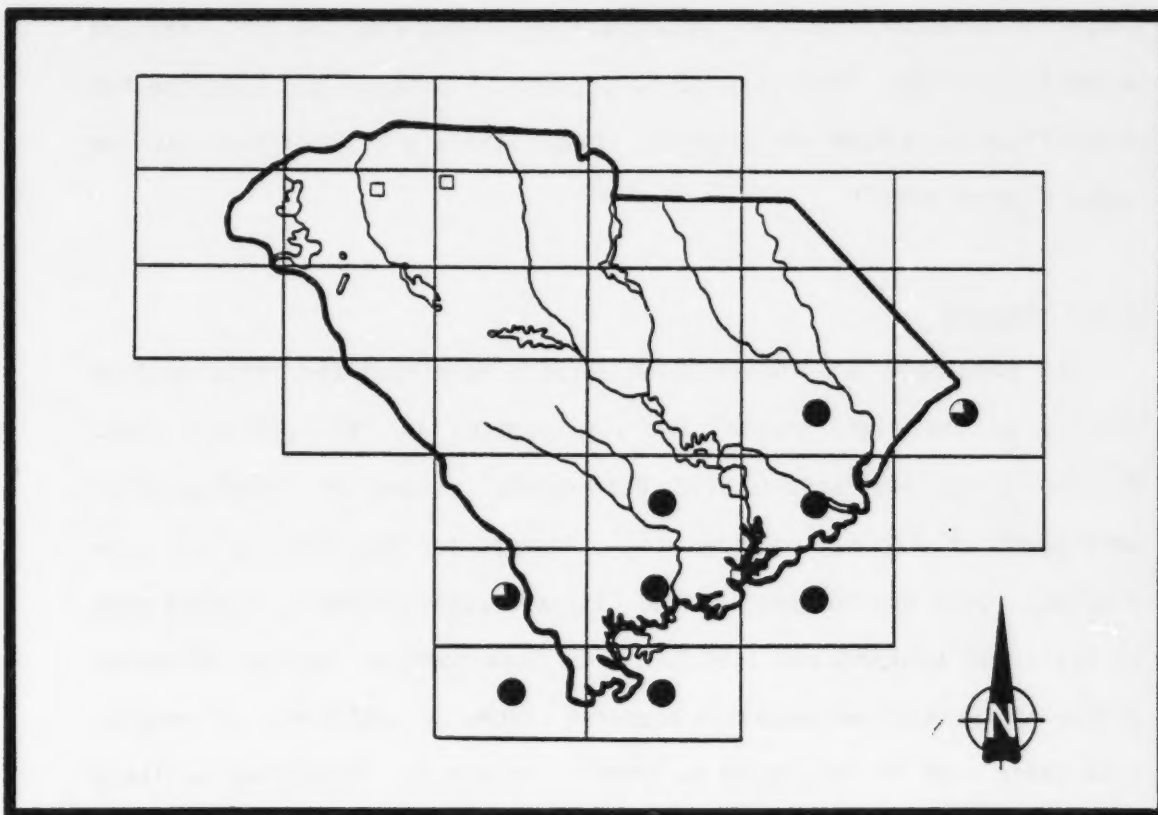
Inventory coverage	Classification	Scale	Date	Resolution	Agency
Wando River Study	Vegetational	-	1975	-	S.C. Water Resources Commission
Non-forested tidal wetlands (not published)	Vegetational	1:24,000	1976	1 acre	S.C. Wildlife and Marine Resources Department
Santee and Cooper River Basins	Hydrology/Soils Vegetation (Cowardin et al.) to the subclass level including special modifiers	1:24,000	1982	1-3 acres	S.C. Wildlife and Marine Resources Department
Coastal Plains (National Wetlands Inventory)	Hydrology/Soils Vegetation (Cowardin et al.) to the class level only	1:24,000 1:100,000	1982	1 acre	U.S. Fish and Wildlife Service

National Wetlands Inventory (Figure 2.2-2). A limited mapping project for the Wando River basin near Charleston was produced in 1975 by the South Carolina Water Resources Commission. Mapping of the Santee and Cooper River Basins has been undertaken by SCWMRD with the U.S. Fish and Wildlife Service. This work is at a scale of 1:24,000 and uses the FWS classification system of Cowardin et al (1979) with modifications for added mapping detail.

2.2.3 Georgia

The USDA Soil and Conservation Service developed the first wetland mapping of the eight coastal Georgia counties in 1977 (Table 2.2-3). Wetland classifications derived from aerial photograph interpretation were combined with soil and hydrology factors for computerized map production. This Map Information and Display System (MIADS) produced maps at scales of 1:20,000 and 1:24,000. The Department of Natural Resources Office of Planning and Research prepared statewide land usage and vegetative cover maps in 1977 based on LANDSAT resources. Bottomland wetlands are defined in this mapping.

Coastal Georgia has been mapped (Figure 2.2-3) at 1:24,000 and 1:100,000 scales by the U.S. Fish and Wildlife Service as part of the National Wetlands Inventory. The system of Cowardin et al. (1979) was used only to the class level for this mapping.



LEGEND
SEPTEMBER 1983

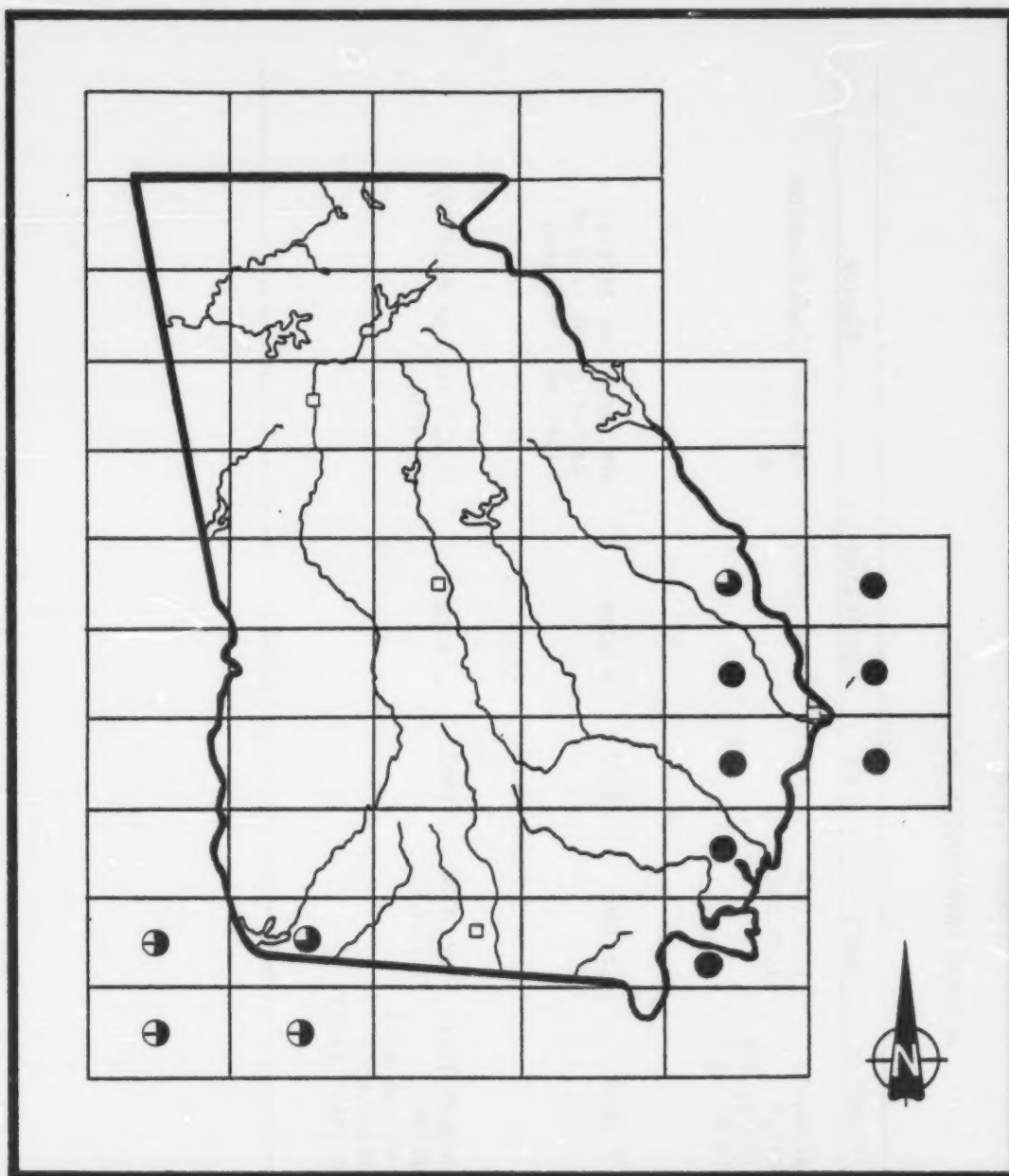
- ⊙ IN PROGRESS
- LARGE SCALE DRAFT OVERLAYS OR MAPS AVAILABLE
- LARGE SCALE FINAL OVERLAYS OR MAPS AVAILABLE
- SMALL SCALE AND LARGE SCALE MAPS AVAILABLE
- ⊙ SMALL SCALE MAPS ONLY

Figure 2.2-2. Status of the National Wetlands Inventory in South Carolina.
Source: U.S. Fish and Wildlife Service. October 1983.

TABLE 2.2-3

WETLAND INVENTORIES IN GEORGIA

Inventory coverage	Classification	Scale	Date	Resolution	Agency
Coastal wetlands (eight coastal counties)	Vegetational community/ hydrology/soils (Martin et al.)	1:20,000 1:24,000	1977	3-10 acres	USDA Soil Conservation Service
Statewide land classi- fication/vegetative cover	LANDSAT data	varied	1977	1 acre	Ga. Dept. of Natural Resources, Office of Planning & Research
Coastal wetlands (National Wetlands Inventory)	Hydrology/Soils/ Vegetation (Cowardin et al.) classified only to the class level	1:24,000 1:100,000	1982	1 acre	U.S. Fish and Wildlife Service



LEGEND
SEPTEMBER 1983

- IN PROGRESS
- LARGE SCALE DRAFT OVERLAYS OR MAPS AVAILABLE
- LARGE SCALE FINAL OVERLAYS OR MAPS AVAILABLE
- SMALL SCALE AND LARGE SCALE MAPS AVAILABLE
- SMALL SCALE MAPS ONLY

Figure 2.2-3. Status of the National Wetlands Inventory In Georgia.
 Source: U.S. Fish and Wildlife Service. October 1983.

2.2.4 Florida

Various state agencies and the U.S. Fish and Wildlife Service have produced substantial mapping in south and northwest Florida (Table 2.2-4). Large portions of this work are at a rather small scale (>1:100,000).

The Kissimmee-Everglades mapping project is concerned with energy flux and land-use implications of mapped vegetation communities. Chronological presentations for circa 1900 (primitive), circa 1953 and 1973 land-use conditions were prepared. Mapping was performed at scales of 1:250,000 and 1:63,360 with greatest emphasis placed on Lee, Hendry and Collier Counties within the Kissimmee-Everglades basin.

A survey of forested wetlands was produced in 1976 by the University of Florida Center for Wetlands at a scale of 1:500,000. Several subclassifications were defined in that project but a single forest-wetlands category was the sole forest vegetation descriptor actually included in final mapping. The Northeast Gulf River Basin study prepared 1:24,000 scale mapping of wetlands for regional and local land use planning. The South Florida Water Management District prepared wetlands mapping in 1976 based on soil hydrology and vegetation communities for a number of south Florida counties at scales of 1:500,000 and 1:24,000. The Center for Wetlands prepared mapping of wetlands in the St. Johns River Water Management District in 1979 at scales of 1:63,360 and 1:253,440.

TABLE 2.2-4

WETLAND INVENTORIES IN FLORIDA

Inventory coverage	Classification	Scale	Date	Resolution	Agency
Wetlands in the Kissimmee-Everglades Basin of south Florida	Vegetational community (Univ. of Fla.)	1:250,000	1976	10 acres	University of Florida - Center for Wetlands
		1:63,360		3 acres	
Coastal Wetlands	Vegetational community	1:125,000	1975	40 acres	Fla. Dept. of Natural Resources - Bureau of Coastal Zone Planning
Forested wetlands throughout the state	Vegetational community/hydrology (Univ. of Fla.)	1:500,000	1976	10 acres	University of Florida - Center for Wetlands
Northeast Gulf River Basin	Vegetational community/soils (FDNR)	1:24,000	1976	-	USDA Soil Conservation Service
Wetlands in the St. Johns River Water Management District	Vegetational community (Univ. of Fla.)	1:63,360 1:253,440	1979	15 acres	University of Florida - Center for Wetlands
Central and Southern Florida Flood Control District	Vegetational community/hydrology	1:500,000 1:24,000	1976	10 acres 2 acres	South Florida Water Management District
South and Northwest Florida (National Wetlands Inventory)	Hydrology/Soils/Vegetation (Cowardin et al.) to the subclass and water regime level.	1:24,000 1:100,000	1982	1 acre	U.S. Fish and Wildlife Service

South and northwest Florida have been mapped extensively by the U.S. Fish and Wildlife Service as part of the National Wetlands Inventory (Figure 2.2-4).

2.2.5 Alabama

The Alabama Marine Environmental Sciences Consortium has conducted four mapping projects in that state's two coastal counties, Mobile and Baldwin, with incentives derived from the federal Coastal Zone Management Act of 1972 (Table 2.2-5). The first of these projects inventoried wetlands up to the 50-foot contour with the subsequent designation of ecologically critical areas. The second effort principally dealt with salt and brackish vegetative species mapping. Maps on a scale of 1:24,000 were produced for this study in 1976. The final two projects concentrated on freshwater wetlands below the 10-foot contour. This series of maps are at a scale of 1:24,000 using state-developed vegetation classification systems.

The U.S. Fish and Wildlife Service, as part of the National Wetlands Inventory, has performed mapping in the two coastal counties (Figure 2.2-5). These maps were produced at a scale of 1:24,000.

In response to local and regional planning requirements, the USDA Soil Conservation Service completed wetlands mapping in 1976 for the Northeast Gulf Rivers Basin and the Alabama River Basin. This mapping was prepared at a scale of 1:24,000 using USGS 7.5-minute topographic maps as well as county photo index maps (Alabama River Basin) and county road maps when USGS maps were not available.

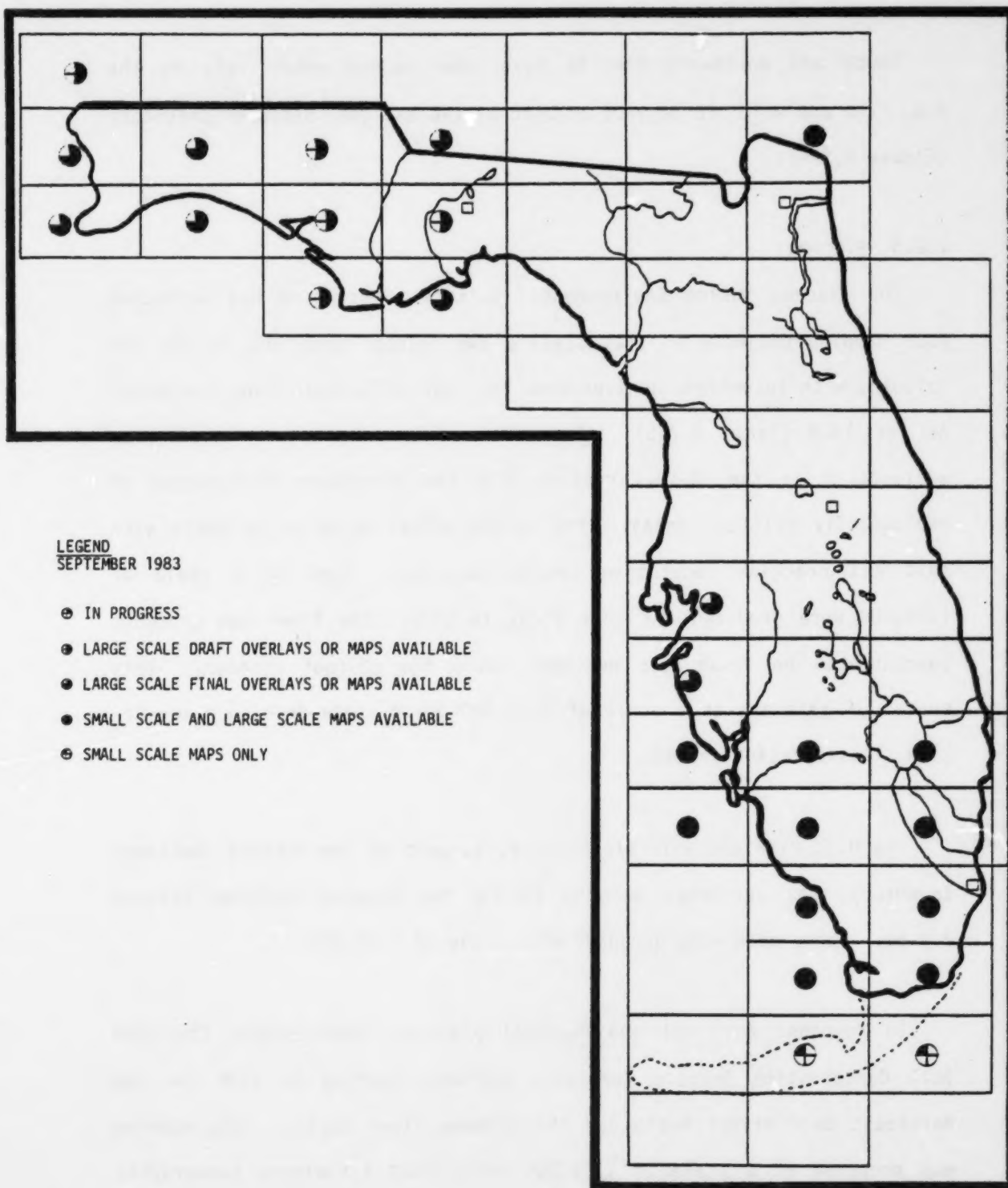


Figure 2.2-4. Status of the National Wetlands Inventory in Florida.
Source: U.S. Fish and Wildlife Service. October 1983.

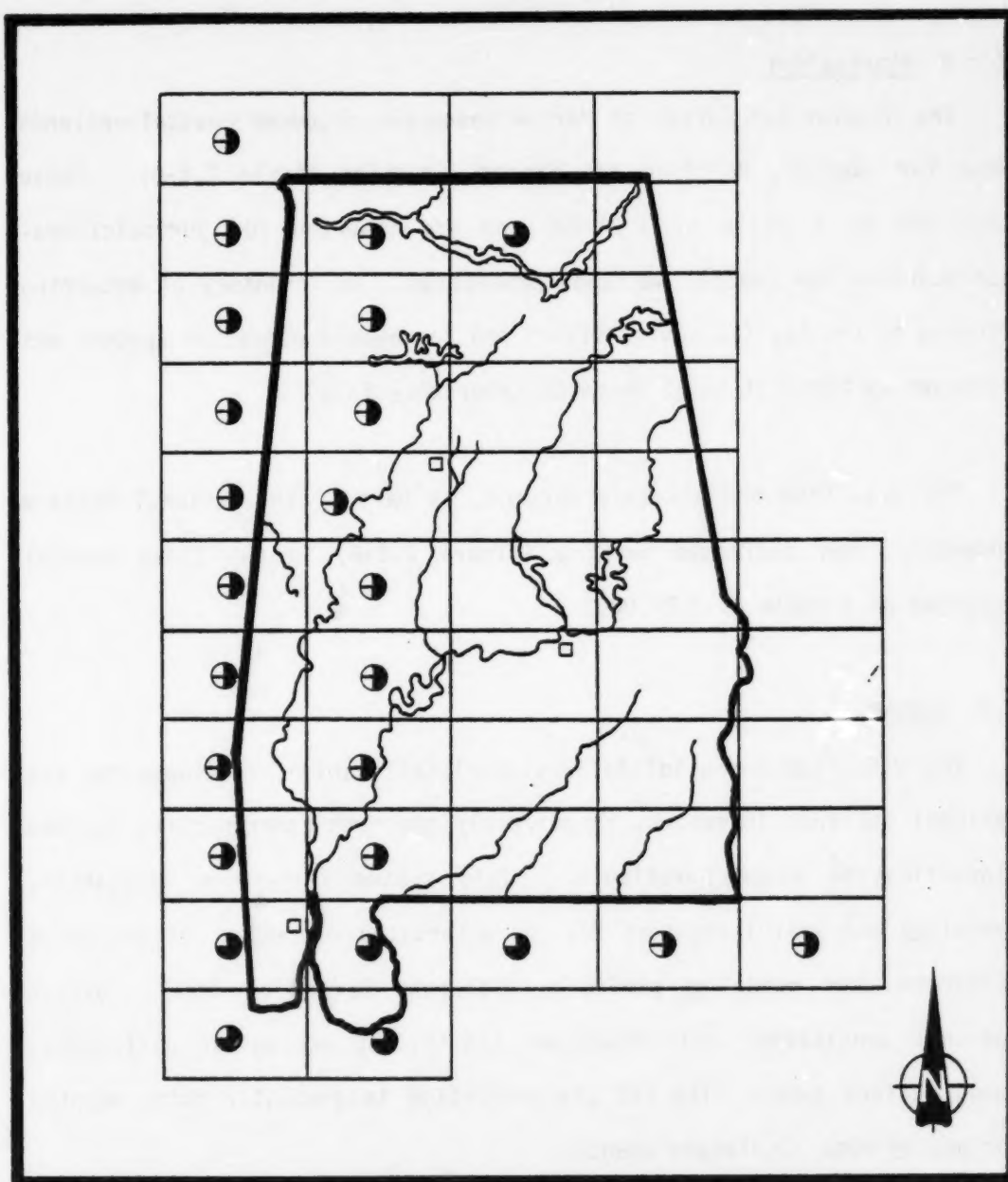
TABLE 2.2-5

WETLAND INVENTORIES IN ALABAMA

Inventory coverage	Classification	Scale	Date	Resolution	Agency
Lower Mobile delta (primarily freshwater marshes)	Vegetational (species)	-	1963	-	Ala. Dept. of Conservation Pittman-Robinson Project (F. X. Lueth)
Coastal wetlands up to the 50' contour (ecologically critical areas)	Vegetational (community)	1:24,000 1:62,500	1975	1-3 acres	Marine Environmental Science Consortium Dauphin Island Sea Lab
Salt and brackish habitats in Mobile and Baldwin Counties up to the inland/upland boundary	Vegetational (species)	1:24,000	1976	1 acre	Marine Environmental Science Consortium Dauphin Island Sea Lab
Northeast Gulf Rivers Basin	Vegetational (Martin et al.)	1:24,000	1976	20 acres	USDA Soil Conservation Service
Alabama River Basin	Vegetational (Martin et al.)	1:24,000	1976	20 acres	USDA Soil Conservation Service
All coastal wetlands in Mobile and Baldwin Counties below the 10' contour, south of the Hwy 90 causeway	Vegetational (community)	1:24,000	1981	1 acre	Marine Environmental Science Consortium Dauphin Island Sea Lab

TABLE 2.2-5
(continued)
WETLAND INVENTORIES IN ALABAMA

Inventory coverage	Classification	Scale	Date	Resolution	Agency
Northeast Gulf Coast Wetlands Mapping (National Wetlands Inventory)	Hydrology/Soils Vegetation (Cowardin et al.; to the subclass and water regime level)	1:24,000	1982	1 acre	U.S. Fish and Wildlife Service
All coastal wetlands in Mobile and Baldwin Counties below the 10' contour, north of the Hwy 90 causeway	Vegetational (community)	1:24,000	1983	1 acre	Marine Environmental Sciences Consortium Dauphin Island Sea Lab



LEGEND
SEPTEMBER 1983

- IN PROGRESS
- ⊖ LARGE SCALE DRAFT OVERLAYS OR MAPS AVAILABLE
- ⊕ LARGE SCALE FINAL OVERLAYS OR MAPS AVAILABLE
- ⊗ SMALL SCALE AND LARGE SCALE MAPS AVAILABLE
- ⊕ SMALL SCALE MAPS ONLY

Figure 2.2-5. Status of the National Wetlands Inventory in Alabama.
Source: U.S. Fish and Wildlife Service. October 1983.

2.2.6 Mississippi

The Mississippi Bureau of Marine Resources produced coastal-wetlands maps for Jackson, Harrison and Hancock Counties (Table 2.2-6). These maps are at a scale of 1:24,000 and are intended for jurisdictional applications for coastal wetlands protection. An inventory of estuarine marshes in the Bay St. Louis, Biloxi and Pascagoula estuarine systems was produced by the Gulf Coast Research Laboratory in 1973.

The U.S. Fish and Wildlife Service, as part of the National Wetland Inventory, has performed mapping (Figure 2.2-6) in the three coastal counties at a scale of 1:24,000.

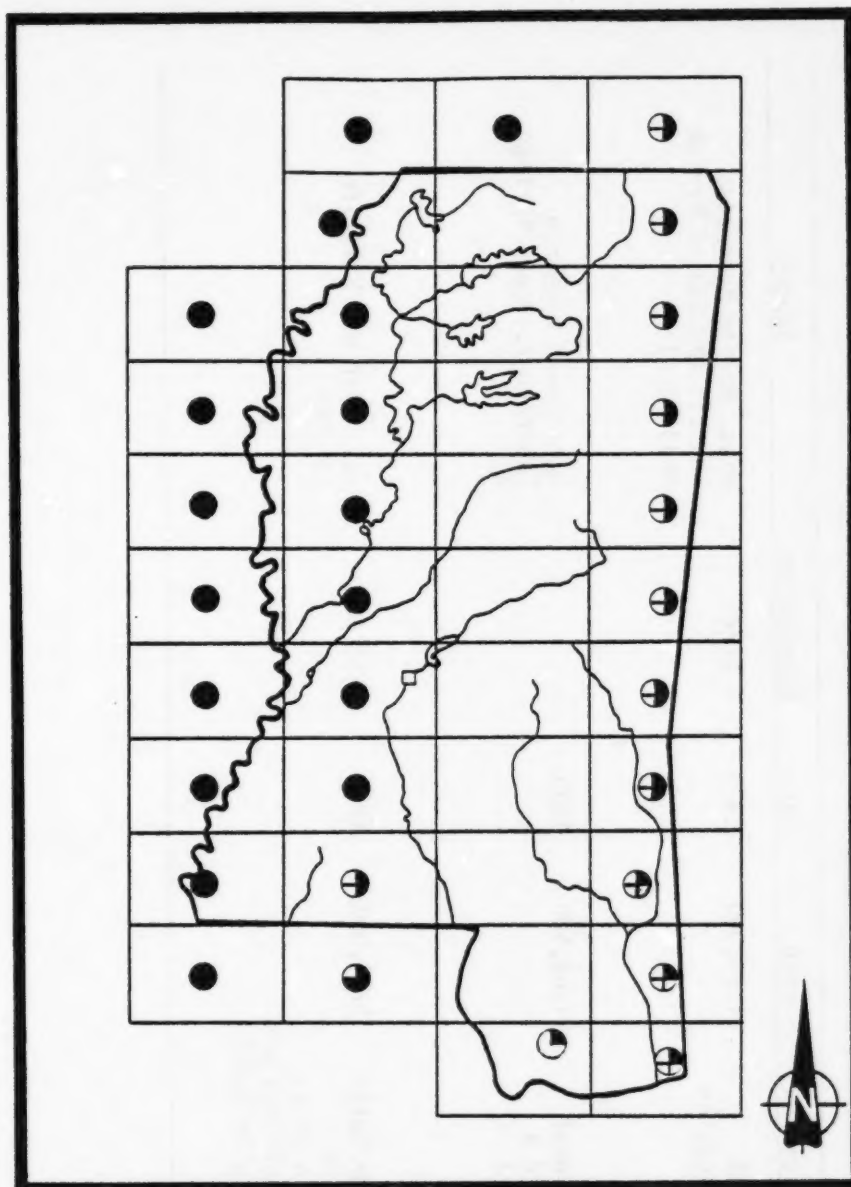
2.3 SUMMARY

The U.S. Fish and Wildlife Service classification, developed for the National Wetlands Inventory, is currently the most comprehensive wetland classification system available. This system relies on vegetation, hydrology and soil indicators for characterizing wetlands. It addresses different user needs by providing different levels of detail, offers regional consistency and recognizes significant ecological differences among wetland types. The FWS classification is gradually being adopted for use by most regulatory agencies.

Mapping efforts in the six Region IV coastal states were inventoried. Figures were used to depict the status of the FWS National Wetlands Inventory as of October 1983.

TABLE 2.2-6
WETLAND INVENTORIES IN MISSISSIPPI

Inventory coverage	Classification	Scale	Date	Resolution	Agency
Coastal Wetlands in Jackson, Harrison and Hancock Counties	no formal classification	1:24,000	1973	1 acre	Miss. Marine Resources Council (Bureau of Marine Resources)
Coastal Marshes (St. Louis, Biloxi and Pascagoula estuarine systems)	Vegetational (Penfound & Hathaway)	1:62,500	1973	-	Gulf Coast Research Laboratory, Ocean Springs, MS
Mississippi Coastal Wetland Mapping (National Wetlands Inventory)	Hydrology/Soils Vegetation (Cowardin et al.; to the subclass and water regime level)	1:24,000	1983	1 acre	U.S. Fish and Wildlife Service



LEGEND
SEPTEMBER 1983

- ⊕ IN PROGRESS
- ⊙ LARGE SCALE DRAFT OVERLAYS OR MAPS AVAILABLE
- ⊗ LARGE SCALE FINAL OVERLAYS OR MAPS AVAILABLE
- SMALL SCALE AND LARGE SCALE MAPS AVAILABLE
- ⊙ SMALL SCALE MAPS ONLY

Figure 2.2-6. Status of the National Wetlands Inventory in Mississippi.
Source: U.S. Fish and Wildlife Service. October 1983.

2.4 LITERATURE CITED

- Cowardin, L., V. Carter, F. Golet and E. LaRue. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish & Wildlife Service, Office of Biological Services, Washington, D.C. #FWS/OBS-79/31. 103 pp.
- EPA. 1983. Freshwater wetlands for wastewater management EIS. Phase 1 report. U.S. Environmental Protection Agency, Atlanta. EPA 904/9-83-107. 380 pp.
- Martin, A.C., N. Hotchkiss, F.M. Uhler and W.S. Bourn. 1953. Classification of wetlands of the United States. U.S. Fish and Wildlife Service, Washington, D.C. Special Scientific Report Wildlife, No. 20:14 pp.
- Penfound, W.T. and E.S. Hathaway. 1983. Plant communities in the marshlands of southeastern Louisiana. Ecological Monographs 8: 1-56.
- Shaw, S.P. and C.G. Fredine. 1956. Wetlands of the United States. U.S. Fish and Wildlife Service, Washington, D.C. Circ. 39: 67 pp. (cited in Cowardin et al., 1979).

3.0 PROFILE OF EXISTING SALTWATER-WETLAND DISCHARGES

A survey was conducted to identify and obtain information on existing saltwater-wetland discharges. On-site observations were made in order to further understand the saltwater-wetland systems and discharge methods in each state.

An information survey program was initiated to identify and characterize existing saltwater-wetland discharges in USEPA Region IV's six coastal states. A list of possible wetland dischargers was obtained from the appropriate state departments in North Carolina, South Carolina, Georgia, Alabama and Mississippi. Florida reported no permitted discharges into saltwater wetlands. A survey form (Table 3.0-1) was then sent to 154 designated dischargers. The information obtained includes physical characteristics of the saltwater wetland, discharge frequency, duration and amount, monitoring programs and any other special requirements. Phone contacts also were made in order to identify possible dischargers. The total number of saltwater wetland discharges surveyed and the respondents are presented by state in Table 3.0-2.

Field trips to identified discharge sites also were conducted. These on-site observations were made to further understand the saltwater-wetland systems and discharge methods in each state. Sites in Alabama and Mississippi were visited in August 1983; and North Carolina, South Carolina and Georgia sites were visited in September 1983. Summaries of these site visits and the results of the inventory program conducted are discussed by state in Sections 3.1 through 3.6.

TABLE 3.0-1

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION IV
SALTWATER WETLANDS FOR WASTEWATER MANAGEMENT EIS
WETLANDS DISCHARGE SURVEY

NAME OF DISCHARGER: _____

ADDRESS: _____

DATE: _____

DISCHARGE SOURCE: _____
(treatment plant, seafood processing, etc.)

Please describe the type of wetland you discharge to and wastewater characteristics by answering the following questions.

1. Wetland Area Characteristics*

- a. Size of wetland area, in acres _____
- b. Area of land draining to wetland area, in acres _____
- c. Distance from wastewater discharge to estuary or ocean/Gulf downstream of wetland area, in feet _____
- d. Vegetation (algae, weeds, grasses, etc.)

Type

Approximate percentage of wetland area covered

- e. Soil (from county soil survey and other information)

Type

Approximate percentage of wetland area covered

*NOTE: If you discharge into a tidal river or creek, check here _____ and describe characteristics of the wetland closest to your discharge.

TABLE 3.0-1
(continued)
U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION IV
SALTWATER WETLANDS FOR WASTEWATER MANAGEMENT EIS
WETLANDS DISCHARGE SURVEY

2. Engineering Information

- a. Total capacity of wastewater treatment _____
(gallons per day)
- b. Wastewater treatment processes (specify capacity of each process
in gallons per day)
 - i) Primary treatment _____
 - ii) Secondary aeration and clarifier(s) _____
 - iii) Nutrient removal and other processes _____
 - iv) Storage _____
- c. Characteristics of wastewater entering wetland (yearly average)
 - i) Flow, in gallons per day _____
 - ii) Biochemical oxygen demand, in mg/l _____
 - iii) Suspended solids, in mg/l _____
 - iv) Ammonia nitrogen, in mg/l _____
 - v) Chlorine residual, in mg/l _____
 - vi) Total nitrogen, in mg/l _____
 - vii) Nitrate & nitrite nitrogen, in mg/l _____
 - viii) Total phosphorus, in mg/l _____
 - ix) Ortho phosphorus, in mg/l _____
 - x) Other parameters (e.g. metals) _____
- d. Specify significant seasonal and/or more frequent variations in
wastewater characteristics:
- e. Sludge treatment and disposal techniques:
- f. Back-up method of wastewater disposal (if any):

TABLE 3.0-1
(continued)
U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION IV
SALTWATER WETLANDS FOR WASTEWATER MANAGEMENT EIS
WETLANDS DISCHARGE SURVEY

g. How long have you been discharging into this water body?
What is the frequency of discharge (daily, weekly, continuous,
etc.)? _____

h. List types of industry discharging to this treatment facility
(applies primarily to municipal discharges):

i) Type(s) _____

ii) Flow(s), in gallons per day _____

iii) Yearly average concentrations,
if known, in milligrams per liter

- Metals _____

- Pesticides _____

- Other compounds (please specify) _____

i. Type of outfall for releasing wastewater to wetland area and
associated construction costs:

i) Channel _____

ii) Outfall pipe _____

iii) Sprayers _____

iv) Other (specify type) _____

v) Year of installation _____

3. Regulatory Requirements

a. Type and frequency of sampling
or in-stream monitoring _____

b. Special maintenance requirements
(if any) _____

c. Other special requirements due to
wetland discharge (if any) _____

d. What is the water use classification of water body or wetland
receiving the discharge? _____

TABLE 3.0-2
NUMBER OF SALTWATER-WETLAND DISCHARGES SURVEYED
BY STATE AND THE NUMBER OF RESPONDENTS

State	Survey Forms Distributed	Number of Respondents	Number of Respondents Discharging to Brackish Waters (mostly Tidal Creeks)
North Carolina	60	5	2
South Carolina	29	9	8
Georgia	34	13	7
Florida ^a	0	0	0
Alabama	12	1	0
Mississippi	19	2	2
Total	154	30	19

^aFlorida officials indicated there were no saltwater wetland discharges, therefore survey forms were not distributed.

The difficulties in presenting a concise profile of saltwater wetland discharges in USEPA Region IV involve wetland definition, existence of discharges, and retrieval of information from individual dischargers. Each state, as well as individual dischargers define a saltwater wetland differently. Therefore, saltwater-wetland discharges are not clearly identifiable. Individual states do not necessarily keep records of permitted dischargers as distinctively saltwater or freshwater wetland, or wetland/non-wetland users. Additional wetland dischargers other than those named on lists provided by the states may be permitted but are not readily identified as saltwater-wetland discharges.

The survey results show that there are no discharges directly onto saltwater wetlands. The majority of respondents, however, identified discharges into tidal creeks. The effects that these tidal creeks have on an individual wetland are dependent on the physical, chemical and biological components of that particular wetland. For example, due to tidal fluctuation, not all tidal creeks inundate the surrounding wetland. Because of the problem of wetland definition, respondents to the questionnaire clearly had difficulty in describing the wetland into which they discharge.

3.1 NORTH CAROLINA

The North Carolina Department of Natural Resources and Community Development, Division of Environmental Management identified 60 discharges into waters classified as salt water within the coastal counties. Of the 60 discharges, three are from the Wilmington Region

(southeast), and 57 are from the Washington Region (northeast). The majority (39) of discharges in the Washington Region are seafood companies (packing and/or processing plants), seven discharges are from wastewater treatment plants and the remaining eight discharges are from utilities, industry or unidentified. The three known discharges in southeast North Carolina are municipal-wastewater treatment plants.

The total response rate of the 60 discharges surveyed was 8.3 percent. Of the five responses, three indicated non-saltwater wetland or discontinued discharges. Since the majority of those surveyed did not respond, the results are inconclusive. Specific information concerning the discharge survey responses are included in Table 3.1-1.

Field trips were conducted in mid-September 1983 to two municipal-waste treatment plants in coastal North Carolina. The findings of these visits supplement the brief data received from the two other discharges.

Southport, North Carolina is served by the Southport Municipal Wastewater Treatment facility which discharges into Doshier Creek. This small tidal creek is surrounded by Spartina and Juncus marsh. A stand of cattails was near the discharge pipe, which was not clearly visible due to vegetation cover.

Morehead City, North Carolina has been served by the Morehead Municipal Wastewater Treatment facility since 1964, with a flow of approximately 1 mgd. The biochemical oxygen demand and suspended solids limitations are 30 mg/l. The facility discharges into Calico Creek, a

TABLE 3.1-1
PROFILE OF SALTWATER WETLAND DISCHARGES IN USEPA REGION IV BASED ON SURVEY RESPONSES

State/ Discharge	Wetland size (acres)	Distance (ft) from discharge to estuary/ocean/gulf downstream of wetland	Vegetation	Discharge to tidal creek or river	Time since discharge began (yrs)	Discharge frequency	Total capacity of waste- water treat- ment(MGD)	Waste- water treat- ment processes, capacity of each process (MGD)	Yearly average flow (MGD)	8005 (mg/l)	Sus- pended solids (mg/l)	Type of outfall
<u>North Carolina</u>												
Municipal Wastewater Treatment Plant	NA	NA	NA	Yes	19	Continuous	4.0	Primary-4.0 Secondary-4.0	2.9	28	14	Drainage ditch
Seafood Processing Plant	NA	NA	-	Yes	25.5	6 da/week 8 mo/yr	0.000008	Primary (chlorine)	-	-	-	-
<u>South Carolina</u>												
Subdivision Treatment Plant	-	-	-	Yes	-	Continuous	0.035	Secondary aeration+ clarifier 20,115 gpd Storage 7,875 gpd	0.18 to 0.025	17	20	Pipe
Public Wastewater Treatment Plant	46	Approximately 2500 to 3000	Woods, grass, Yes 80% tupelo, red maple, etc.	Yes	1 mo.	Daily	5.0	Primary 2.5 Secondary 2.5 Polishing pond Storage 5.0	0.3	10	15	Pipe with diffuser header
Public School Treatment Plant	-	Approximately 200 from high water mark of tidal creek	Spartina	Yes	11	5 da week 9 mo/yr	0.04	Secondary 0.06 Storage 0.002	0.0074	5	7	Pipe
Municipal Wastewater Treatment Plant	-	Approximately 3000	Marshgrass	Yes	15	Continuous	1.5	Primary 1.5 Secondary 1.5	1.0	10	10	Pipe
Municipal Wastewater Treatment Plant	-	-	-	Yes	Began 10/1/83	-	2.0	Primary 2.0 Secondary 2.0	2.0	30	30	Pipe
Apartment Complex Treatment Plant	-	-	Marshgrass	Yes	8	-	0.035	Primary 0.035 Secondary 0.035 Nutrient removal storage 0.035	0.019	15	15	Pipe
Treatment Facility	-	Approximately 3.5 miles to Atlantic Ocean	Marshgrass	Yes	15	Continuous	0.0075	-	-	15	15	-

TABLE 3.1-1
(continued)
PROFILE OF SALTWATER WETLAND DISCHARGES IN USEPA REGION IV BASED ON SURVEY RESPONSES

State/ Discharge	Wetland size (acres)	Distance (ft) from discharge to estuary/ocean/Gulf downstream of wetland	Vegetation	Discharge to tidal creek or river	Time since discharge began (yrs)	Discharge frequency	Total capacity of waste- water treat- ment(MGD)	Waste- water treat- ment processes, capacity of each process (MGD)	Yearly flow (MGD)	8005 (mg/l)	Sus- pended solids (mg/l)	Type of outfall
<u>Georgia</u>												
Paper Company Industrial Treatment Facility	1,120	0	75-80% Grasses	Yes	42 (31 yrs untreated; 11 yrs treated)	Continuous	44	Primary 44 Secondary 44	36.994	21	39	Pipe
Pulp and Paper Mill	Discharge is to estuary	100,000 to ocean	90% Spartina	Yes	50+	Continuous	33	Primary 33 Secondary 33	30	50	75	-
Municipal Treatment Plant	-	-	-	Yes	8	Daily	0.550	Secondary	0.500	10	10	Pipe
Municipal Treatment Plant	-	-	Reeds, grass etc.	Yes	10	Daily	1.0	Primary 0.85 Secondary 0.85	NA	NA	NA	Pipe
Municipal Treatment Plant	-	-	-	Yes	22	Continuous	0.85	Secondary Storage (15.1 acre-pond)	0.3 0.3	-	-	Pipe
Municipal Treatment Plant	Not measured	Not measured	Unknown	-	40+	-	2.25	Primary 2.50 Secondary 2.25 Storage/ 2.25 Nutrient Removal	1.3 to 1.6	<10	<10	Pipe
Municipal Treatment Plant	-	-	-	Yes	-	Daily	0.368	Primary 0.368 Secondary 0.368	0.255	2.7	3.2	Pipe
<u>Mississippi</u>												
Treatment Plant	20	1000 to estuary	80% Marshgrass	Yes	23	Daily	0.27	Primary 0.27 Secondary 0.27	0.22	20	5	Pipe
Treatment Plant	10 to 500	2000	95% Grass/ weeds	-	11	Continuous	0.008	Primary 0.008 Secondary 0.008 Nutrient Removal 0.008	-	-	-	Roadside ditch

NA indicates the respondent did not have the information available.

- indicates the respondent did not answer.

Flows are presented in mgd, million gallons per day, unless otherwise noted.

tidal creek surrounded by marsh. High water levels prevented access to the immediate point of discharge. Downstream from the discharge point, active shrimp harvesting was occurring in waters that were posted.

3.2 SOUTH CAROLINA

A list of 29 individual municipal and industrial discharges to saltwaters was provided by the South Carolina Department of Health and Environmental Control, Bureau of Water Pollution Control. The profile described is based on eight responses; one questionnaire response indicated that the treatment facility was still in the planning stage and had not been constructed.

The wastewater treatment plants responding to the questionnaire in South Carolina all discharge to tidal creeks. These discharges do not go directly to saltwater marsh areas, however, some marsh areas may be inundated during high tide.

Typical vegetation in South Carolina saltwater wetlands is comprised of marsh grasses such as Spartina or Juncus. One respondent specifically reported 80 percent coverage by swamp tupelo, red maple, black willow, tallow tree, sweet gum and water elm (indicative of freshwater wetlands) along with weeds, grasses and shrubs. The individual sizes of the wetlands are generally unknown. The frequency of discharge ranges from daily to continuous, and the period of discharge ranges from one month to 15 years. The typical effluent discharged into saltwater wetlands is secondary-treated domestic sewage. This treatment process involves a

minimum of secondary aeration and clarification. The yearly average flow ranges from 0.007 mgd to 2.0 mgd from discharge pipes. Table 3.1-1 presents individual responses to the survey.

Field visits conducted in September supplement the survey data and allow first-hand knowledge to be gained concerning the wetland systems and the different types of discharges in South Carolina. The two municipal wastewater treatment plant discharge sites visited are discussed below.

Mt. Pleasant, South Carolina is serviced by three facilities - the Sneefarm Subdivision, the Main Plant and the Parish Place Plant. The three are reportedly going to be combined into one facility in the near future. A site visit was made to the Main Plant in Mt. Pleasant, a 1.5 mgd facility serving Mt. Pleasant since 1968. The plant will be upgraded to approximately 3 mgd. Ultraviolet disinfection technology will be used when the upgrading is completed. The facility discharges into a tidal creek that flows through a saltwater marsh leading to the Intracoastal Waterway. At high tide the tidal creek is noted to be rich with mullet.

St. Andrews, South Carolina public service district is served by a standard secondary-treatment plant using aeration and clarifiers. Drying beds are used for sludge treatment, after which the material is disposed of in an approved landfill. The Pierpont Plant discharges 1.5 mgd into nearby Church Creek and has been operating continuously for 15 years. Depending on tidal fluctuations, two other small creeks may also be inundated. The tidal area is surrounded by Spartina and Juncus marsh.

3.3 GEORGIA

The state of Georgia provided the highest percentage of returned information forms. The Georgia Environmental Protection Division, Water Protection Branch provided a list of 34 known industrial and municipal saltwater-wetland discharges of which 13 responded to the questionnaire. These 13 included five industrial discharges, seven municipal discharges and one utility. Information provided by the 13 dischargers indicated that only seven actually discharged effluent to a saltwater area. One industrial respondent reported they discharged directly into an estuary, however, they did not consider this a wetland and did not complete the questionnaire.

Information reported by the seven dischargers to saltwater areas generally indicated discharges to tidal creeks. The size of each particular wetland is not reported except for one case in which the wetland is 1,120 acres. The type of vegetative cover is either unknown or described as weeds or marsh grasses. Respondents indicate that they have been discharging secondary-treated wastewater on a daily or continuous basis for an overall average of 30 years. The yearly-average flow discharged ranges from approximately 0.3 mgd of domestic wastewater to 37 mgd of industrial wastewater. Table 3.1-1 profiles existing saltwater-wetland discharges in Georgia.

The discharges of three different facilities were observed during site visits conducted in mid-September 1983. The following narratives discuss the site visits.

St. Simons Island, Georgia is served by a 1.3 mgd wastewater treatment facility that has operated since 1945. Characteristics of the effluent include a BOD limitation of 20 mg/l and a suspended solids limitation of 30 mg/l. The discharge flows into Dunbar Creek which is tidally influenced. The creek is within a Spartina/Juncus saltwater marsh and contains many tarpon and mullet in the vicinity of the discharge. Spartina near the point of discharge appeared taller and denser than that not proximal to the discharge.

Wilmington Island, Georgia is served by the Wilmington Park Sewage Treatment Plant. This 200,000 gpd to 300,000 gpd treatment facility discharges to a tidal creek narrowly bordered by Salicornia and Spartina. This tidal creek eventually flows into the Wilmington River. Spartina at the mouth of the creek was not noticeably different from that farther along the river's shore.

Skidaway Island, Georgia is the location of Skidaway Island Utilities which operates a spray-irrigation system. The total capacity of wastewater treatment is 750,000 gpd. Sprayers have been used daily for the last nine years. The area sprayed is woodland and most wastewater percolates into the ground. Overflow washes into a canal which, in turn, drains into a marsh.

3.4 FLORIDA

The Florida Department of Natural Resources, Division of Marine Resources reported that the state of Florida has not permitted any saltwater-wetland dischargers. A 201 Study is being prepared that is investigating the feasibility of using a saltwater wetland for wastewater discharge in Jacksonville Beach, Florida, yet there are no existing applications of wastewater onto saltwater marshes. Questionnaires therefore were not distributed in the state. A variety of other wetland ecosystems exist in Florida that are used as discharge sites for treated wastewater and they are detailed in this document's companion report for the Freshwater Wetlands EIS.

3.5 ALABAMA

The state of Alabama had the lowest percentage response to the wetland-discharge questionnaire mailed. One negative response was received from a list of 12 potential saltwater-wetland discharges provided by the Water Division of the Alabama Department of Environmental Management. The respondent reported that they did not fit any of the categories mentioned in the survey.

Four municipal and two seafood-processing discharges were visited in coastal Alabama to examine the wetland systems. Three of the municipals were non-saltwater wetland discharges. The saltwater areas are discussed in the narratives that follow.

Bon Secour, Alabama was the site of one seafood processor visit. Although the rate of discharge could not be determined, the small size of the operation suggested that the rate of discharge would be low. Discharge was directly into a large bayou. There was a Spartina fringe along the bayou at this site, but the banks were fairly elevated and not considered wetland marsh.

Bayou La Batre, Alabama is serviced by a sewage-treatment plant that discharges directly into Portersville Bay through a discharge pipe that crosses a saltwater wetland. This plant was designed to handle 1 mgd but, because of the number of seafood processors in Bayou La Batre (one of which was visited), the ability of this plant to adequately process the large volume of wastes is severely limited, particularly during the summer months when processing activity is at a peak.

Pt. Aux Pins, Alabama is a predominantly Juncus saltwater wetland near Bayou La Batre. This marsh was visited because it is the site for a proposed demonstration project to assess the feasibility and effects of applying wastewater discharge onto a saltwater marsh. The proposed study would use wastewater from a seafood-processing plant at Bayou La Batre and spray irrigate wastewater on various marsh plots.

3.6 MISSISSIPPI

The Mississippi Department of Natural Resources, Bureau of Pollution Control provided a list of 19 private and industrial discharges from three Mississippi Gulf counties. The profile is based on a 10 percent response rate.

The two responses were not clearly identified as saltwater wetland discharges. One treatment plant serves a utility and discharges to a bayou. This plant has operated for 23 years, discharging approximately 270,000 gpd of secondary treated wastewater. Sludge is disposed of at an approved sanitary landfill. The wetland is approximately 20 acres, and 80 percent of the acreage is marsh grass. The second respondent reported discharge to a roadside ditch. The wetland vegetation is 95 percent grass and weeds over an area that measures from 10 to 500 acres. The yearly average flow for this treatment plant is 8,000 gpd for the past 11 years. The respondent indicated that the ditch is solely for industrial use. Table 3.1-1 specifies the details of the two questionnaire responses for Mississippi.

It is difficult to assess saltwater wetland discharges in Mississippi as well as in the other states because of the lack of clearly defined wetlands. Field visits were conducted in August 1983 to examine saltwater-wetland systems and discharges in Mississippi and are discussed below.

Pass Christian, Mississippi municipal treatment plant is designed to discharge 700,000 gpd. Discharge is into a small ditch which eventually enters a Juncus marsh adjacent to Portage Bayou. There was no means of access to the area where the ditch entered the marsh.

Discovery Bay, Mississippi is a housing and marina development on Portage Bayou at Pass Christian. At present, only the marina and a few townhouses have been constructed. Sewage is treated by a package plant that discharges less than 1,000 gpd through a pipe at the edge of the bayou. Juncus was the predominant vegetation at the point of discharge. No difference was observed between vegetation at the point of discharge and that farther along the shore away from the discharge point.

Diamondhead, Mississippi is a large residential development that includes a golf course, tennis courts and a marina. Sited on the north shore of St. Louis Bay, this development had one package plant that discharged into salt water. At the time of our visit, only a few homes were serviced by this unit and discharge was less than 1,000 gpd. This discharge entered a ditch which flowed into a large tidally - influenced channel bordered by marsh on the far side of the discharge ditch.

3.7 SUMMARY

The response (19.5 percent) to the survey questionnaires was considered low. Of the 30 responses obtained, the majority (19) indicated that they discharged into brackish waters, mostly into tidal creeks. None stated that they discharged directly onto saltwater wetlands. During the site visits, wastewater discharges into tidal creeks were observed on several occasions. Marsh vegetation at the mouth of or bordering these creeks appeared taller and denser at one site but, for the most part, did not appear to differ from adjacent areas less likely to be influenced by the discharge.

4.0 INSTITUTIONAL CONSIDERATIONS

The objective of this section is to present and discuss federal institutional requirements which govern the use of saltwater wetlands as a receiving body for wastewater discharges and to describe the Region IV regulatory programs administered by the individual states. Unresolved institutional issues are also addressed.

A large part of federal institutional involvement pertaining to wastewater discharges in saltwater wetlands stems from the Clean Water Act. Programs established through the Act and discussed here are the Water Quality Standards Program as administered by U.S. Environmental Protection Agency (EPA); the National Pollutant Discharge Elimination System Permit Program also administered by the U.S. EPA; the 201 Construction Grants Program, also under U.S. EPA administration; and the Dredge and Fill Permit Program administered by the U.S. Army Corps of Engineers. Two other federal programs, Fish and Wildlife Coordination (which involves the U.S. Fish and Wildlife Service and National Marine Fisheries Service responsibilities) and the National Shellfish Sanitation Program administered by the Public Health Service, both involve advisory duties when a proposed water resource development activity could adversely impact fish, wildlife or shellfish of a given water body.

State programs or procedures which impact the feasibility of discharging wastewater to saltwater wetlands are presented in this chapter. These programs and procedures include water quality standards, discharge permits and methodology for determining wasteload allocations for wetlands, the process for prioritizing projects for 201 Construction

Grant Program funding, and various state coastal area management and protection plans.

The most significant issue which is addressed in this chapter is the procedural and regulatory variation among the various programs which deal with saltwater wetlands. These differences include:

- . lack of consistency in defining a saltwater wetland, including its landward and seaward boundaries;
- . variation in the number of water use classifications and standards which may apply to saltwater bodies;
- . differences in assigning water quality standards to similar use classifications, e.g., shellfish harvesting waters;
- . variation in evaluating the effects of proposed discharges on wetlands.

All of these differences are in themselves issues that will be significant in permitting activities within saltwater wetlands in the states and also along state boundaries or interstate waters.

4.1. FEDERAL PROGRAMS

4.1.1 Water Quality Standards Program

The Water Quality Standards Program (40 CFR 131.2) is the foundation of the nationwide strategy for water quality management. Section 303 of the Clean Water Act authorizes establishment of water quality standards to protect public health, public welfare and water quality. Each state has the responsibility of developing water quality standards, while the U.S. EPA has review and approval authority. Permits for any construction activities and discharges are issued or denied based primarily on adherence to water quality standards.

Stream segments are delineated, and associated use classifications are established as part of a state's Water Quality Management Plan. Water quality criteria are then established to assure that designated uses will be maintained and protected. Effluent limitations for each wastewater management facility that discharges to waters of the U.S. are determined to meet established water quality criteria. For an effluent-limited segment, secondary treatment is required of publicly-owned treatment works (POTWs). For a water quality-limited segment, additional treatment may be required, dependent on the number and type of pollutant sources within and upstream from the segment. An effluent-limited segment is one where water quality standards will be met if POTWs provide secondary treatment of effluent. A water quality-limited segment is one where standards will not be met by POTWs providing secondary treatment alone, and this failure necessitates implementation of more advanced treatment controls or strategies.

Current regulations associated with water quality standards do not include rigid technical procedures for states to utilize in revising water quality standards. However, federal regulations for water quality standards revised in November 1983 now offer increased guidance for determining use attainability, utilizing site-specific criteria, applying anti-degradation policy, varying (upgrading or downgrading) levels of aquatic protection and applying general policies on mixing zones and variances.

Key considerations are: assessing the attainability of the designated water use, defining natural background conditions, whether to develop general or site-specific standards, and protection of downstream water uses.

Regarding uses of wetlands as waters of the United States, most wetlands in Region IV are designated for the same usage as the adjacent water body, generally fish and wildlife use. Water quality standards are numerically established at minimum levels for attaining the designated use. Discharges of wastewater can not be allowed to reduce water quality below the level needed to maintain the designated water use. At the same time, the designated water use cannot imply that degradation of existing water quality is warranted. Natural background conditions need to be defined in order to determine the water use that is attainable. Clearly, dischargers should only be required to maintain water quality requirements that correspond to water uses attainable without the discharge. Dissolved oxygen and pH in wetland waters are quality constituents that are typically lower than standard limits due solely to natural conditions.

Site-specific water quality standards can be established by states. Compared to more general all-inclusive standards, site-specific standards are more likely to achieve the designated water use without being more stringent than necessary. On the other hand, field procedures on which to base site-specific standards can be time-consuming and expensive.

Finally, water quality standards for a wetland may need to be established so that the water quality use classification of a downstream estuary or coastal bay can be attained. Effects of downstream water uses may be less noticeable for saltwater wetlands than they are for freshwater wetlands that may, for example, be located upstream of a water supply intake. Designated water uses for an estuary or coastal bay that may be more stringent than wetland water uses include swimming or shellfishing. Because waters can move from a downstream estuary or coastal bay upstream to a wetland, downstream water use designations also can affect a saltwater wetland in a direct manner.

Each of the Region IV coastal states maintains different water use classifications as shown in Table 4.1-1. No standards have been developed based on environmental characteristics of the various wetland types. North Carolina and South Carolina do designate that wetland waters can have dissolved oxygen concentrations and pH levels which, due to natural conditions, fall below normal standards for non-wetland waters.

Florida and Georgia have specially designated certain waters as "outstanding" state waters. Wetlands within or upstream of "outstanding" state waters may be subject to more strict discharge limitations than if the "outstanding" state waters designation is not in effect.

TABLE 4.1-1
AGENCIES AND WATER USE CLASSIFICATIONS FOR EPA REGION IV COASTAL STATES

State	Agency	Water use classifications which can apply to Coastal Waters
Alabama ¹	Department of Environmental Management, Water Division	Class B - Swimming and other whole body water contact sports Class C - Shellfish harvesting Class D - Fish and wildlife Class E - Agriculture and industrial water supply Class F - Industrial Operations Class G - Navigation
Florida ²	Department of Environmental Regulation, Division of Environmental Programs	Class II: Shellfish propagation or harvesting Class III: Recreation, propagation and management of fish and wildlife Class IV: Agricultural and industrial water supply Class V: Navigation, utility and industrial use Outstanding Florida waters
Georgia ³	Department of Natural Resources, Environmental Protection Division, Water Protection Branch	Class B: Recreation Class C: Fishing, propagation of fish, shellfish, game and other aquatic life Class D: Agricultural Class E: Industrial Class F: Navigation Class G: Wild river Class H: Scenic river Class I: Urban stream
Mississippi ⁴	Department of Natural Resources, Bureau of Pollution Control, Water Division	Class B - Shellfish harvesting areas Class C - Recreation Class D - Fish and wildlife
North Carolina	Department of Natural Resources and Community Development, Division of Environmental Management	SA - Shellfish waters SB - Primary Recreation SC - Fishing and secondary recreation
South Carolina	Department of Health and Environmental Control, Bureau of Water Pollution Control	SAA - Outstanding resource waters SA - Shellfishing waters SB - Primary recreation waters SC - Secondary recreation and fishing waters

NOTES: ¹The state of Alabama has not developed a specific saltwater use classification system. Of these water use classifications, several can be applied to saltwater use, including: 'B', 'C', 'D', and 'G'.

²The state of Florida has not developed a specific saltwater use classification system. Of these water use classifications, several can be applied to saltwater use, including: Class II, Class III, Class V and Outstanding Florida Waters.

³The state of Georgia has not developed a specific saltwater use classification system. Of these water use classifications, several can be applied to saltwater use, including: Class B, Class C and Class F.

⁴The state of Mississippi has not developed a specific saltwater use of classification system. Of these water use classifications, several can be applied to saltwater use, including: 'B', 'C' and 'D'.

4.1.2 National Pollutant Discharge Elimination System (NPDES) Permit Program

4.1.2.1 Regulatory Background/Overview

Section 402 of the Federal Water Pollution Control Act (PL 92-500, as amended) established the National Pollutant Discharge Elimination System process for permitting all point source pollutant discharges into the waters of the United States. This permit process is applicable to all potential dischargers to saltwater wetlands. Additionally, in accordance with this Act, all municipal dischargers were to achieve secondary treatment by 1 July 1977, unless stricter controls were needed to meet water quality standards. Pursuant to Section 402, the Environmental Protection Agency (EPA) or an EPA-approved state agency must issue an NPDES permit prior to the discharge of wastewater into U.S. waters. An NPDES permit, when issued, should include (at a minimum):

- . effluent limits,
- . schedule for complying with effluent limits,
- . monitoring and reporting requirements, and
- . sludge disposal requirements.

Depending upon the nature of the receiving waters and/or the surrounding environment, special protection procedures may be required as part of the permit. This may be true for wetland areas that are considered to be valuable and sensitive ecosystems. Special requirements are discussed in Section 4.1.2.2.

Section 318 of the Act approves and permits aquaculture systems under the NPDES program. An "aquaculture project" is a "managed water area which uses discharges of pollutants into that designated area for the maintenance or production of harvestable freshwater, estuarine, or marine plants or animals" (40 CFR 122.56). The EPA Administrator is authorized to promulgate regulations establishing procedures and guidelines appropriate to the "discharge of a specific pollutant or pollutants under controlled conditions associated with an approved aquaculture project" Section 318(a), CWA . In addition, following EPA approval, each state is authorized to administer its own aquaculture permit program.

4.1.2.2 NPDES Permitting Process and its Relationship to Wastewater Management Saltwater Wetlands

NPDES permit issuance is typically based on compliance with established water quality standards and waste load allocations for a particular receiving water body. Wetland discharges are required to be permitted under NPDES regulations.

General permits may be written to cover a category of discharge types within a particular geographic or political area. These permits are usually written for similar types of discharge sources, and carry requirements specific to that discharge type. Currently, this measure is interpreted as permitting only groups having similar discharge sources. Groups with similar discharge sites, such as wetlands, are not included under this regulation even though some groups of wetland discharges could meet the regulatory requirements. It is possible, however, that there are discharges to wetlands currently permitted under this mechanism.

Prior to discharging to a U.S. water body, an NPDES permit application must be submitted to EPA or to an EPA-approved state environmental agency. The following items must be included on the NPDES permit application:

- . list of all pollutants which may be apparent within wastewater and which must comply with water quality requirements,
- . average and maximum quantities of wastewater to be discharged,
- . frequency and volume of discharge, and
- . name/type of receiving water.

The amount of detail to be provided on an application varies according to the size of the discharge. Small domestic discharges are required to provide the least level of detail on the permit. For instance, Federal Short Form A for municipalities and Short Form D for commercial establishments ask applicants for the name of the receiving water, not the type (such as wetlands). Characteristically, wetland discharges in EPA Region IV tend to be small and many are commercial establishments (i.e. seafood processing plants). Therefore, the Short Form would be applicable. Larger discharges (>5 MGD) generally use Form 2C which requires more detailed information on receiving waters.

Another consideration in the NPDES permitting process is the establishment of a wasteload allocation, or the maximum daily wasteload allowable. Wasteload allocations are established for all state surface waters so that water quality standards can be met and designated uses protected through consideration of background conditions and pollution sources along a designated water body segment. Effluent limits are then assigned to the individual dischargers into that water body segment.

An area of discharge is determined to be either effluent-limited or water quality limited before wasteload allocations are set. If it is effluent-limited, then technology-based treatment requirements are made a part of the permit requirements and represent a minimum level of treatment required. For publicly owned treatment works discharging to wetlands, this would probably represent at least secondary treatment prior to discharge. If, however, water quality standards can not be met with secondary treatment, then it is considered a water quality-limited segment and thus more stringent effluent limits must be established to maintain in-stream water quality standards.

Pursuant to federal requirements of the NPDES program, the discharger, following application approval, is responsible for giving the following information to the regulatory agency:

- . schedule for commencing discharge,
- . design plans for location and type of outfall,
- . construction procedures, and
- . start-up and monitoring procedures.

In addition, the permitting agency can periodically inspect discharge facilities to determine whether implementation procedures are being conducted properly. Such authority applies for both municipal and seafood processing discharges.

The NPDES permit can include special requirements that a discharger must meet. These requirements might be necessary, for instance, when the

receiving water body is a wetland and special measures are needed to protect established uses or attain applicable water quality standards or effluent limits. Special requirements can include (but are not limited to):

- . seasonal or more frequent variations in discharge or monitoring requirements,
- . outfall design to enhance wastewater distribution and assimilation,
- . special treatment operation or maintenance,
- . wastewater disinfection requirements,
- . requirements conditional on future events,
- . sludge management requirements, and
- . special operator training.

4.1.3 201 Construction Grants Program

4.1.3.1 Regulatory Background

The 201 Construction Grants Program was authorized by Section 201 of the Clean Water Act. The program constitutes the procedures required to obtain Federal funding for the planning, design and construction of municipal wastewater treatment systems. Fundable systems include those for collection, treatment and disposal of wastewater. Amendments were made in 1982 to the 201 Program affecting the scope and funding percentages of wastewater facilities projects (Section 4.1.3.2). The 201 Program is applicable to saltwater wetlands only when a municipality wishes to receive a construction grant for a treatment facility which will discharge to a saltwater wetland. The availability of construction grant funding for wetland alternatives is based on the process by which the

applicable state prioritizes 201 projects and the degree to which the control or access of wetlands are required and eligible.

4.1.3.2 Construction Grants Process

This section discusses the three steps to the construction grants program and recent changes, with emphasis on applicability to saltwater wetlands disposal.

- . Step 1 - facilities planning,
- . Step 2 - facilities design, and
- . Step 3 - facilities construction.

Generally, these three steps take place in consecutive order except in cases where Steps 2 and 3 are blended together.

Some portions of the construction grants process have been revised since 1981:

- . Grants for Steps 1 and 2 are no longer given separately; instead, allowances are included in Step 3 grants for facilities planning and design activities.
- . Step 3 grant advances are possible for small communities from the state environmental agency.
- . Construction grants are now available only for secondary or more stringent treatment, new interceptors and connecting sewers and infiltration/inflow corrections.
- . After October 1, 1984, grants will be made to handle current needs, not to exceed year 1990 needs.
- . Engineering services are required and fundable for one year after construction completion.

- . Secondary treatment definition has been expanded to include oxidation ponds, lagoons, ditches and trickling filters.

The fundability potential of a discharge system to wetlands as a means of wastewater management and the applicability of EPA's innovative/alternative technology program are not defined.

Step 1 of the construction grant process (Facilities Plan) must present all possible wastewater management alternatives, evaluate feasible alternatives and select a preferred alternative. This preferred alternative must meet the following conditions:

- . must be needed to improve existing conditions and/or conditions 20 years into the future,
- . be cost effective when considering costs, environmental impacts, financial considerations, reliability, energy use, implementability and recreation,
- . involve the public, and
- . conform to an approved water quality management plan and waste-load allocations.

As part of the evaluation of alternatives, environmental impacts must be considered including possible permits which may be required based on activities and potential impact. For instance, if dredging and filling of a wetland is part of an alternative being evaluated, the Corps of Engineers must be consulted. If a dredge and fill permit would be required, the Corps will identify alternative locations and other environmental considerations.

Mitigative measures must be introduced if it is determined that sensitive environmental areas (including wetlands) will be impacted by the preferred alternative. Environmental impacts which may be considered with a potential discharge to saltwater wetlands include:

- . impacts on listed endangered or threatened species,
- . impact on water quality for designated uses, e.g., recreation, shellfish harvesting,
- . visible changes, i.e., increase or decrease or change in vegetation type or turbidity which may negatively impact fish and wildlife habitat,
- . impacts during construction, and
- . public health.

Present regulations require the preparation of an EIS if there is potential for significant adverse impacts on wetlands, or if any major portion of the treatment works is located within a wetland area. Other conditions may also necessitate preparation of an EIS.

Following completion of a draft facilities plan, an opportunity for review is provided by federal, state and local agencies. The federal role in this process varies from state to state, contingent upon whether a state has been delegated facilities plan review and approval authority.

Many problems can occur to hamper facilities planning efforts, particularly if efforts required of other agencies are not completed. For instance, if the involved state(s) has not developed a wasteload allocation for the water body proposed to receive treated wastewater, planning

efforts may be delayed. Another fairly recent stipulation to the 201 process is the result of 1981 Amendments to the Clean Water Act. These amendments specify that each state review and, if necessary, revise its water quality standards by December 29, 1984 or the issuance of construction grant funds would be stopped.

Design (Step 2) and construction (Step 3) procedures do not vary greatly from project to project. Once a project is high enough on the state priority list certain procedures need to be followed in order to assure construction grant funding eligibility. Considerations associated with a project which includes a wetland discharge are:

- . possible need for a dredge or fill permit under Section 404 of the Clean Water Act,
- . field testing of innovative/alternative technologies,
- . specification during design phase of construction and operation-maintenance methods associated with chlorine/other disinfectant, since worker safety and chlorine-wastewater by-products on wetlands are of primary concern,
- . construction specifications as output from design phase can include methods to minimize wetland disturbance, maximize wetland and assimilative capacities and other mitigative and/or enhancement measures,
- . plan of operation must include any unique staff needs and timing considerations for construction, start-up and operation,
- . an operation and maintenance manual to include start-up and operation procedures associated with wetlands use,
- . construction activities monitoring must also be provided, and
- . after construction starts, one year of engineering services is needed to supervise and train operator/troubleshoot serious problems.

4.1.4 Corps of Engineers Permit Program

The Dredge and Fill Permit Program is administered by the Corps of Engineers (COE) as promulgated by Section 404 of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500). Section 404 authorizes the Secretary of the Army, through the Chief of Engineers, to issue or deny permits for disposal of dredged or fill material in the waters of the United States.

A Section 404 Dredge and Fill Permit may be required if the discharge of dredge or fill materials in waters of the United States will occur as a result of construction of wastewater facilities in wetland areas. Dredging in saltwater wetlands can take place for a number of reasons related to wastewater discharges, including:

- . pipeline construction,
- . channels, aerators, weirs, levees and storage ponds for controlling the flow and distribution pattern of wastewater, and
- . other alterations for improving system efficiency.

The Corps' responsibilities in terms of the use of wetlands for wastewater discharges are limited to 404 permit review and issuance. As such, they are not directly involved in the permitting of wetlands for wastewater discharge.

The Corps' dredge and fill permitting process begins with a preliminary assessment and application submittal to determine the extent of environmental reviews required, ranging from a categorical exclusion to a full EIS procedure. In the case of categorical exclusion, no application is required.

Public notice, including the findings of the preliminary assessment, is then given to all interested parties and to agencies with a required role in the process. This step in the Corps' review process is especially significant since it gives public agencies at all government levels, private groups and individuals the opportunity to voice comments on all the effects of project construction and operation (including social, economic and environmental factors affecting wastewater management in saltwater wetlands).

If necessary, a public hearing is held, the comments are evaluated and any environmental reviews necessitated in the preliminary assessment are conducted. Following completion of the environmental review, the permit decision is made and the application is either issued or denied. Table 4.1-2 presents a summary of the criteria the Corps considers in their permit decision-making process.

In addition to the Corps review of dredge and fill permit applications, the EPA also shares certain responsibilities. Input to the permit review process is also provided by the Department of Interior, Fish and Wildlife Service (FWS), and the Department of Commerce, National Marine Fisheries Service (NMFS). The Fish and Wildlife Coordination Act and the National Shellfish Sanitation Program and their relationship to wastewater disposal in saltwater wetlands is discussed in Sections 4.1.5 and 4.1.6, respectively.

TABLE 4.1-2
CORPS OF ENGINEERS PERMIT EVALUATION CRITERIA

-
- . Evaluation of economic, social and environmental costs versus benefits
 - . Extent of public and private need
 - . Desirability of alternative locations
 - . Cumulative impacts
 - . Effects on wetlands
 - . Conservation of wildlife and prevention of direct and indirect losses
 - . Evaluation for compliance with applicable effluent standards, water quality standards and management practices
 - . Consideration of effects on the enhancement, preservation or development of historic, scenic and recreational values
 - . Effects on wild and scenic rivers
 - . Interference with adjacent properties or water resource projects
 - . Impacts on navigation
 - . Compliance with state coastal zone management programs
 - . Evaluation of potential impact to marine sanctuaries
 - . Consistency with state, regional or local land use classifications, determinations or policies
 - . Effects on flood losses, impact of floods, human health, safety and welfare and the natural and beneficial values served by flood plains
-

Source of Information: 33 CFR 320.4 and 323

The EPA's responsibilities under Section 404 in conjunction with the COE include:

- . development of criteria for evaluating locations for discharge of dredged material under 404(b)(1),
- . ultimate authority to veto permits on environmental grounds under 404(b)(1),
- . the designation of geographic areas and ecosystems where EPA will make final determinations on permit applications,
- . assistance to states in developing responsibility for delegated programs,
- . determination of boundaries of navigable waters, and
- . the authority to halt illegal discharges.

Guidelines developed by EPA in reviewing Corps 404 permit applications are presented in Table 4.1-3. Where the EPA denies authorization for dredge and fill activities, the Corps' application will, in turn, be denied. This holds true, too, for other required federal, state or local dredge and fill authorization.

A federal rule is being proposed by the U.S. Army Corp of Engineers which would amend policies and procedures associated with certain nationwide federal permits for activities in waters of the United States (Federal Register, March 29, 1984). Where permitted by the NPDES program, outfall structures will be permitted by the Corps of Engineers under the proposed rule. However, the Corps' district or division engineer must make a determination that the individual and cumulative adverse impacts are minimal (Section 330.5(a)(7) of the proposed rule) following notification by the applicant to the Corps that the outfall is

TABLE 4.1-3

SUMMARY OF EPA CRITERIA FOR APPROVAL OF DREDGED OR FILL MATERIAL
DISCHARGE UNDER SECTION 404(b)(1) OF THE CLEAN WATER ACT

-
- . Where practicable alternatives exist with less adverse impacts on the aquatic ecosystem and no other significant adverse impacts; such alternatives include:
 - activities resulting in no discharge
 - alternative discharge locations;
 - . If water quality standards would be violated;
 - . If toxic effluent standards would be violated;
 - . If the continued existence of endangered species would be violated;
 - . Where requirements to protect marine sanctuaries would be violated;
 - . Unless considerations of the economic impacts on navigations are overriding, where there are
 - significant adverse effects on human health or welfare, municipal water supplies, plankton, fish, shellfish, wildlife and special aquatic sites
 - significant adverse effects on aquatic life and other aquatic-dependent wildlife
 - significant adverse effects on aquatic ecosystem diversity productivity and stability
 - significant adverse effects on recreational, aesthetic and economic values;
 - . Specific procedures for making these determinations have been set forth in Subparts C-F of 40 CFR 230.
-

Source of Information: 40 CFR 230

being planned. The Corps' district or division engineer can impose conditions or supplementary requirements in association with 404(b)(1) or other federal guidelines. No permit will be granted which includes, the alteration of wetlands identified as "important" unless the district engineer concludes that benefits would outweigh damages. Seven general categories to define "important" wetlands are listed in the Federal Register (July 22, 1982):

- wetlands having significant biological functions (e.g. food chain production, species resting, and spawning),
- wetlands set-aside for studies or as sanctuaries or refuges,
- wetlands whose alteration would affect drainage, sedimentation or salinity patterns,
- wetlands at barrier islands, reefs and bars which shield other areas from waves, storms and other activities resulting in erosion and other types of damage,
- wetlands that are valuable water storage areas,
- wetlands that are prime groundwater recharge areas, and
- wetlands which provide significant and necessary purification of incoming waters.

4.1.5 Fish and Wildlife Coordination

The Fish and Wildlife Coordination Act (the Act), PL 85-624 as amended by PL 89-72, was established with the general purpose of requiring that fish and wildlife receive consideration in water resource development activities. The Act states that whenever a department or agency proposes an activity which will impound, divert, control or modify a body of water for any purpose, the FWS must be consulted. The FWS reviews a proposed activity for potential damage to wildlife and makes recommendations for measures to mitigate or compensate for damage,

including consideration of whether alternative, non-wetland sites are available. This is applicable to Section 404 review of a dredge and fill permit applications, for wastewater disposal activities, and NPDES permit application review. The FWS is also authorized under the Act to conduct investigations in order to determine the effects of domestic sewage on wildlife and to report the results of the investigations to Congress.

Most of the FWS review responsibilities are focused on Section 404 permit applications. However, several aspects of wastewater management in wetlands have also drawn the concern of the FWS. These concerns primarily relate to:

- . wildlife habitat alterations, e.g., water quality degradation, and
- . accelerated eutrophication and vegetational changes.

In addition to FWS review responsibilities under the Act, a proposed wetlands discharge project in a coastal area is also subject to NPDES and Section 404 permit review by the National Marine Fisheries Service (NMFS). Criteria used by NMFS in reviewing Corps' 404 permit applications are listed in Table 4.1-4. NMFS, through the authority of the Coastal Management Act, provides reports to Congress on the status of the U.S. shellfish industries. These reports discuss the relationship between water quality and the shellfish industry, the array of issues facing this industry, and state and federal responsibilities in shellfish producing waters.

TABLE 4.1-4

NATIONAL MARINE FISHERIES SERVICE GUIDELINES
FOR ASSESSING WETLAND ALTERATION

-
- . The extent of precedent setting and existing or potential cumulative impacts of similar or other developments in the project area;
 - . The extent to which the activity would directly affect the production of fishery resources (e.g., dredging, filling marshland, reduced access, etc.);
 - . The extent to which the activity would indirectly affect the production of fishery resources (e.g., alteration of circulation, salinity regimes and detrital export);
 - . The extent of any adverse impact that can be avoided through project modification or other safeguards (e.g., piers in lieu of channel dredging);
 - . The extent of alteration sites available to reduce unavoidable project impacts;
 - . The extent to which the activity requires a waterfront location if dredging or filling wetlands is involved;
 - . The extent to which mitigation is possible to offset unavoidable habitat losses associated with a water-dependent project that clearly is in the public interest.
-

Source of Information: National Marine Fisheries Service. 1983.
Guidelines and criteria for proposed wetland
alterations in the southeast region of the U.S.

The Federal Endangered Species Act of 1973 was amended in 1978 to direct the Secretary of the Interior and the Secretary of Commerce to develop plans for the protection of federally-listed endangered or threatened species. The Secretary of the Interior, acting through the FWS, has broad authority to protect and conserve all forms of flora and fauna considered to be in danger of extinction. The Secretary of Commerce, acting through NMFS, has similar power to protect and conserve most marine life.

4.1.6 National Shellfish Sanitation Program

The National Shellfish Sanitation Program (NSSP) evolved in 1925 because of a recognized need for state and federal cooperation in the protection of shellfish waters. It is a cooperative control program in which the Public Health Services' Shellfish Sanitation Branch exercises supervision over the sanitary quality of shellfish shipped in interstate commerce.

These supervisory duties are outlined in Part I of the NSSP, Manual of Operations, Sanitation of Shellfish Growing Areas. The manual itself is intended solely as a guide for states in exercising sanitary supervision over shellfish growing, relaying, purification, and in issuing certificates to shellfish shippers. Part I of the manual develops procedures which are intended as a guide to states in the preparation of their individual shellfish sanitation laws and regulations and for the sanitary control of the growing, relaying and purification of shellfish. In addition, the Public Health Service uses the manual to determine whether a

state's proposed shellfish sanitation program qualifies for endorsement by the Public Health Services' National Shellfish Certification Program.

The federal government's role in the protection of state-owned shellfish waters, therefore, is purely advisory. The NSSP guides the states in setting up shellfish protection programs. Policies or programs that would, for instance, regulate placement of an outfall in relation to shellfish areas are developed at the state level.

The following procedures were outlined by the Shellfish Sanitation Branch in Part I of the Operations Manual. These procedures must be adopted at the state level prior to federal certification of their shellfish protection program:

- . adopt adequate laws and regulations for sanitary control of shellfish industry,
- . make periodical sanitary and bacteriological surveys of growing areas,
- . delineate and patrol areas where harvest is restricted,
- . inspect shellfish plants,
- . conduct inspections, laboratory investigations and control measures necessary to insure that shellfish have been grown, harvested and processed in a sanitary manner, and
- . issue certificates to shellfish dealers complying with sanitary standards and forward copies to the Public Health Service.

The part played by the Public Health Service involves the following:

- annually review state's control program including inspection of a representative number of shellfish-processing plants,
- endorse or withhold endorsement of states' control program, and
- publish a semi-monthly list of all valid interstate shellfish shipper certificates.

Federal supervision of state shellfish sanitary program development based on the above state procedures can, if adopted, have a significant impact on the placement of outfalls in saltwater wetlands.

4.2 STATE PROGRAMS

4.2.1 Alabama

4.2.1.1 Water Quality Standards

The Alabama Department of Environmental Management (ADEM), has established seven water use classifications that are applied to all state waters. The definitions for these seven classes would not limit their application to saltwater areas; however, none of the classes are directed specifically toward saltwater bodies. Class C--shellfish harvesting would apparently include saltwater bodies. Table 4.1-1 lists the seven water use classifications for the state.

General, minimum standards applicable to all state waters include limitations on settleable solids, floating debris, oil, grease and other materials, and toxic or harmful concentrations of sewage, industrial or other wastes. Specific water quality criteria have been developed for each of the seven use classifications. These criteria include specifications for allowable sewage, industrial and other wastes, pH, temperature, dissolved oxygen, toxic substances, taste and odor, bacteria, radioac-

tivity and turbidity. The criteria may differ for each class, but in all cases, have been designed to insure continued use of the waters for the designated purpose. Shellfish harvesting waters must meet standards similar to swimming and public water supply. They must also meet the guidelines of the National Shellfish Sanitation Program (ADEM Regulations, 1981).

ADEM does recognize that natural waters may have characteristics outside the limits established in the water quality criteria. The specific criteria for each of the seven use categories set forth allowable variations for coastal waters, estuaries and tidal tributaries. These allowances apply to pH and dissolved oxygen. There is also a fairly broad allowance for recognition of natural turbidity levels (ADEM Regulations, 1981).

To date, the state has not developed a working definition of where coastal waters stop and coastal wetlands begin, and no distinction is made between open waters and wetlands in assigning use classifications (personal communication). Therefore, the water quality standards for adjacent waters would also apply to wetland areas (personal communication).

4.2.1.2 Discharge Permits

The state also does not distinguish wetlands from other waters of the state for the purpose of permitting wastewater discharges. Specific procedures and guidelines have not been developed for establishing waste-

load allocations and effluent limitations for wetland discharges. Generally, permit limits for industrial discharges to wetlands are developed from EPA (BAT/BCT) guidelines. In the absence of EPA guidelines, best engineering judgement is used. Secondary treatment provides the initial bases for municipal discharge limits. In all cases, an analysis of water use and flow characteristics of the receiving waters are used for determining any higher degree of treatment required.

4.2.1.3 Construction Grants Program

Projects proposing to discharge to saltwater wetlands would be considered eligible for funding under the Construction Grant Program. Since saltwater wetland discharge projects have not yet been funded in the state guidelines indicating what portions of the project are fundable have not been established. If a saltwater project were proposed, it would be prioritized in the same manner as other projects (personal communication).

Permitted freshwater wetland discharges have not been considered to be innovative or alternative projects and have not received any special funding considerations. In any case, other than the monies set aside for funding innovative and alternative technology, Alabama would not have any additional funds available for I&A Projects.

4.2.1.4 Other Programs

The legislature of Alabama through the passage of the Alabama Coastal Area Act established the Alabama Coastal Area Board as an inde-

pendent state agency with the charter to preserve, protect, develop, and where possible, to restore and enhance the natural, cultural, historic, aesthetic, commercial, industrial and recreational resources of the state's coastal area (Coastal Area Management Program, 1979). In order to carry out these responsibilities the legislature provided the coastal board with the power to develop a management program, adopt necessary rules and regulations and to review all uses requiring state permits for compliance with the coastal management program. No state agency can grant a permit for any activity or action within the coastal area until the board determines that the permit would be in compliance with the coastal management program. This permit review authority would apply to uses which contribute to a waste discharge; uses which alter or destroy wetlands; and point and non-point wastewater discharges. Based on this authority, an NPDES permit for a saltwater wetland discharge in Alabama would need to be reviewed and approved by the coastal board.

4.2.2 Florida

4.2.2.1 Water Quality Standards

Specific classifications or water quality standards have not been developed by the Florida Department of Environmental Regulations (DER) for saltwater areas (see Table 4.1-1). However, the state has designated five water classifications: I, potable water supplies; II, shellfish propagation or harvesting; III, recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife; IV, agricultural water supplies; and V, navigation, utility and industrial use. All of these classifications could theoretically be applied to saltwater

areas. For each of the classifications there is an extensive and detailed list of water quality criteria addressing such parameters as floating solids, oil and grease, settleable solids, alkalinity, metals, bacterial quality, dissolved oxygen, nutrients, pesticides, toxics, pH and transparency.

These classifications and standards apply to coastal waters which extend from the three-fathom (18-foot) bottom contour landward to the limit of submerged marine species. Certain saltwater wetlands would be considered coastal waters under this definition. Other saltwater wetlands not considered coastal waters but contiguous to coastal waters would still be considered a part of that water body and possess the same water quality standards.

Florida DER recognizes that certain portions of waters of the state (particularly wetlands) do not meet specific water quality standards due to man-induced or natural causes. The parameters most likely to vary from the standards in wetland areas are pH and dissolved oxygen. Alternative water quality criteria may be applied based on designated water use, extent of biota adaptations to background conditions, evidence of ecological stress and adverse impacts to adjoining waters (FAC 17-3.031). Site-specific alternative criteria offer permanent relief under a given set of background conditions.

Exemptions to specific water quality criteria are also granted for the experimental use of wetlands for low-energy wastewater recycling.

Under Section 17-4.243 (4) FAC (Exemptions from Water Quality Criteria), exemptions from certain criteria may be granted upon petition indicating that the appropriate criteria will not adversely affect public health or adversely impact the biological community in the receiving waters or the contiguous water body. With this exemption, appropriate criteria are not necessarily the background levels. In addition, an exemption has to be renewed every five years based on long-term monitoring data, whereas alternative criteria (Section 7-3.031 FAC) provided experiments designed to lead to the development of new information concerning wastewater disposal to wetlands.

4.2.2.2 Discharge Permits

Under Florida state law, coastal wetlands would be considered waters of the state to the landward extent of specific submerged marine species. Therefore, any discharge to these areas must receive an NPDES permit. Although isolated wetlands may not be considered waters of the state, it is likely that coastal wetlands would not be isolated from other water bodies. Florida is the only state in the study area which has not been granted full authority from EPA to administer the NPDES permit program.

The capacity wetlands have to assimilate nutrients, organics and metals is site-specific and primarily dependent on hydrologic regimes. Standard water quality models are not generally applicable to wetlands and as a result, DER has not used predictive models to determine possible impacts of discharges to wetlands. In instances where ambient conditions warrant site-specific criteria or exemptions, baseline water quality

studies are used to determine the appropriate criteria. If a standard wasteload allocation model is used and it calls for unusually high levels of treatment, a biological assessment is made. The assessment addresses the relationships between current discharges and detectable problems. This approach would be limited for proposed new wetland discharges unless an existing discharge to a comparable wetland system is available for observation.

Additional requirements concerning loading rates and treatment levels have been applied to freshwater wetland discharges. Hydraulic loading rates are usually restricted to 0.5 to 1.0 inch per week. Minimum treatment required would be secondary treatment (Chapter 17-6, FAC) followed by disinfection and storage in a holding pond (with a detention time of three days at design flow) to achieve dechlorination. Nitrification before discharge would be necessary to optimize nitrogen removal in wetlands where the ambient pH level is not conducive for nitrification. Pretreatment to remove phosphorus would also be necessary for flow-through wetlands unless site-specific information is available to indicate long-term storage by the wetland sediments. These above requirements can be modified based on consideration of the type and ambient water quality of the downstream water body. In addition, some form of legal control of the wetland would be necessary in order to restrict public access to the site. Current Florida DER philosophy is not to allow discharges to saltwater wetlands because of their environmental value.

4.2.2.3 Construction Grants Program

The procedure for funding projects under the Construction Grants Program would not differ significantly for projects in Florida proposing to discharge to saltwater wetlands if discharges could obtain a discharge permit. Such projects with a discharge permit would be considered fundable under the 201 Program and they would be placed on the funding priority list in the same way as other projects.

Florida has not yet addressed the question of status for saltwater wetland discharge projects as an innovative and alternative technology. If a project were found to be innovative or alternative, it would be given a small multiplier in the priority formula which could place it slightly higher on the funding list. Otherwise, there would be no preference given an I&A project.

4.2.2.4 Other Programs

Florida has the most extensive coastal area regulatory program of any of the six states. There are two state dredge and fill programs under separate statutory authority; the Development of Regional Impact (DRI) Program for large-scale projects; and two separate coastal permit programs. A review of these program requirements, however, indicates that they may not directly apply to wastewater discharges. As in other states, if modification of the wetland were undertaken, then provisions of the dredge and fill permitting programs would apply. Permits under the state's coastal management program could be required for the siting and construction of treatment facilities but not for a discharge.

4.2.3 Georgia

4.2.3.1 Water Quality Standards

Georgia has not established specific water quality classifications for saltwater areas (see Table 4.1-1). Nine general water quality classes have been developed for classifying all waters of the state, including "coastal waters". There is no specific classification for shellfish harvesting or propagation. However, within the classification for propagation of fish, shellfish, game or other aquatic life, there are designated shellfish harvesting areas which must meet the guidelines of the National Shellfish Sanitation Program.

The Georgia Environmental Protection Division (EPD) does not have an official policy concerning the discharge of treated wastewater to wetlands. EPD does not distinguish saltwater wetlands from coastal waters, therefore the water quality standards given for the adjacent coastal waters would apply to the wetland (personal communication). The state's water quality regulations do, however, recognize that certain natural waters of the state may have a quality that will not be within the standards specified. Although no specific level of variation is recognized, this flexibility should be considered in evaluating wastewater discharges to saltwater wetlands.

4.2.3.2 Discharge Permits

NPDES permits are required for wastewater discharges to wetlands and the permit process is the same as for other wastewater discharges. Permit requirements are based on federal effluent guidelines, secondary

treatment, or some degree of treatment more stringent than secondary where it is necessary to achieve and/or maintain the water quality standards. The Georgia EPD does not use predictive modelling to establish effluent limitations for wetland discharges, but instead, relies on site analyses and qualitative judgments. If a definable channel exists, the discharge might be modelled, but in this case, it would not be considered a wetland discharge.

The Georgia EPD does not have a specific policy in funding of projects which would propose to discharge to saltwater wetlands. The decision would apparently be made on a case-by-case basis by the Division Director. If funding were approved, the project would be placed on the priority list using the same procedures as for any other project.

Wetland discharges would not likely be considered innovative. This would be based on the treatment technique more than the type of disposal proposed. The decision as to whether a project were alternative would be based on a case-by-case review. EPD would not consider saltwater wetland discharge projects to be alternative on a blanket basis (personal communication).

Projects in Georgia with innovative and alternative technologies are funded from monies set aside for I&A technologies on the state's general priority list. The priority system does have special provisions for projects using innovative and alternative technologies.

4.2.3.3 Other Programs

The Georgia Coastal Marshlands Protection Act was passed by the Georgia Assembly in 1970 to insure that Georgia's coastal marshlands were used in the public interest for the benefit of all citizens of Georgia. The Act includes a requirement to obtain a permit for most activities and construction of structures that alter any marshland in the state. The permit review and approval requirements of the Act provide an exception for construction, maintenance and repair of approved water and sewer lines. However, the regulations under the Act also identify depositing of waste material in marshlands as contrary to the public interest. Lagoons and impoundments for waste treatment located in marshlands are also identified as contrary to the public interest. Thus, discharges to coastal wetlands may be subject to the Act.

4.2.4 Mississippi

4.2.4.1 Water Quality Standards

The Mississippi Department of Natural Resources (DNR), Bureau of Pollution Control has established water quality standards for two classifications which are applicable to saltwater. These two classifications are Shellfish Harvesting Areas and Fish and Wildlife. Specific standards have been established for bacteria under Shellfish Harvesting Areas, and under Fish and Wildlife for bacteria, specific conductance, dissolved solids and phenolic compounds. Waters which are classified for shellfish propagation also must meet the requirements set forth in the latest addition of the National Shellfish Sanitation Program, Manual of Operations. The relative proximity of a bacterially-related discharge to

a shellfish harvesting bed will be considered by the Permit Board prior to acceptance of that site for disposal. All of the states' water use classifications are listed on Table 4.1-1.

In addition to standards specific to these classifications, DNR has also established minimum conditions applicable to all waters. These standards require that water be free from settleable solids, floating debris, oil or scum, materials creating color, odor or other nuisance problems and harmful or toxic substances. Also, municipal, industrial and other wastes are required to receive treatment or control in accordance with Sections 301, 306 and 307 of the Clean Water Act. Minimum temperature, pH and dissolved oxygen standards are also given and are applicable to all waters.

The state does not differentiate between saltwater wetlands and other coastal waters for the purpose of determining appropriate water quality standards. The water quality classifications and standards developed by DNR apply to saltwater wetland areas as long as those areas can be classified as waters of the state. A state water body is any water within the jurisdiction of the state except for those which are totally landlocked and privately owned. However, exceptions can be made to the standard water quality criteria for certain state waters that do not fall within established limitations due to natural background conditions or irrevocable man-induced conditions.

4.2.4.2 Discharge Permits

Mississippi was delegated the authority to administer its own pollution discharge permit program (NPDES Program) by EPA in 1974. Mississippi has developed a specialized analysis for determining the wasteload allocation to wetland areas since the application of standard steady-state river models resulted in requirements for extremely high levels of treatment. This specialized analysis involves qualitative evaluations and other site-specific assessments deemed necessary including water quality and eutrophication studies.

4.2.4.3 Construction Grants Program

The State of Mississippi has established a priority system for allocation of funds for projects under the 201 Construction Grants Program. Projects which propose a discharge to wetland areas are considered fundable. However, since no saltwater wetlands discharge projects have been funded as yet, guidelines indicating fundable project portions have not been established. No special consideration is given to wetlands discharge projects based on the fact that the receiving water body is a wetland. The project may, however, rate higher on the priority list due to other factors such as existence of sensitive environmental areas (e.g., shellfish beds). Projects proposing discharge to wetland areas have not, in the past, been considered either alternative or innovative and would, therefore, not be eligible for I&A funding.

4.2.4.4 Other Programs

The Mississippi Coastal Program based largely on the Mississippi Coastal Wetlands Protection Law (49-27-1 through 49-27-69, Mississippi Code of 1972) and the Mississippi Bureau of Marine Resources Enabling Legislation (57-15-1 through 57-15-17) establishes a set of management goals for the coastal area which comprises the state's coastal area policy.

The Coastal Program requires that certain regulated activities secure a permit prior to conducting that activity, based on the Coastal Wetlands Protection Law. Two activities which are subject to the coastal program if they occur in wetland areas are effluent discharges and dredge and fill activities. If the construction of a sewer system is conducted or supported by state or federal agencies in the coastal area, this is also subject to the Coastal Program's permit procedure.

4.2.5 North Carolina

4.2.5.1 Water Quality Standards

North Carolina has established a two-part water quality classification system with a separate group of classifications and specific standards for tidal saltwater areas. All tidal saltwater classes must meet similar standards for chlorophyll a, total dissolved gasses, turbidity, heavy metals, pesticides, phosphorus, PCB's and radioactive substances. Specific classifications must meet further standards for floating solids, other wastes, pH, dissolved oxygen, toxic wastes, temperature and coliform bacteria.

The use classification with the most restrictive criteria for tidal waters is SA, shellfish waters. In addition to standards for temperature, pH, etc., these waters must meet the sanitary and bacteriological standards given in the National Shellfish Sanitation Program Manual of Operations, (PHS, 1965). Waters which meet these standards may also be used for purposes specified in other use classifications. These classifications include SB - Primary Recreation and SC-Fishing and Secondary Recreation (NCAC subchapter 2B, Sections 01 and 02). Table 4.1-1 lists these classifications.

For all three tidewater classifications, a lower dissolved oxygen standard is permitted for "swamp" waters and the state also provides for site specific revisions to the dissolved oxygen standard where certain natural or man-induced conditions warrant (NCAC). This flexibility and recognition of the different natural conditions present in wetlands could be important in the use of wetland areas for wastewater management. North Carolina also designates certain water bodies as nutrient sensitive. In these locations, any increase in nitrogen and phosphorus levels is stringently limited thus, perhaps hindering any discharges.

4.2.5.2 Discharge Permits

As with the other coastal states in Region IV except for Florida, North Carolina has been delegated the authority by EPA to administer the pollution discharge permit program. For effluent limited water bodies, permits would require technology-based treatment levels as a minimum level of treatment. However, if a water body is water quality limited,

the NPDES permit would require greater than secondary treatment. The level of treatment required for discharge to such waterbodies is based on wasteload allocations typically derived by mathematical modeling. North Carolina normally uses a standard dissolved oxygen model for deriving wasteload allocations for wetlands. Modifications to the standard Streeter-Phelps model are used for wetland areas. As appropriate, effluent limits other than those indicated by these models are often used.

4.2.5.3 Construction Grants Program

Each state is given responsibility for establishing a priority list for funding of projects under the 201 Construction Grants program. In North Carolina, as in most states, a formula incorporating many parameters is used to establish funding priority. In general, the North Carolina procedure favors projects that are needed to attain water quality standards and which would serve large populations in areas with potentially more serious or widespread water quality problems.

In a discussion with state personnel in North Carolina, it was revealed that projects proposing to discharge effluent to wetland areas have been approved for funding. These are prioritized on the same basis as other projects. Discharges to saltwater wetlands would be reviewed in much greater detail than freshwater wetland discharges, particularly if the water body in question is one which contains commercially important shellfish, recreational fisheries and/or critical wildlife habitats (personal communication).

The North Carolina Department of Natural Resources and Community Development would not consider wetland discharge projects to be innovative, although based on a case-by-case review they could be considered alternative. Other than funds in the four percent of funds set-aside for innovative and alternative technologies, wetland discharge projects would not be eligible for any special funds (personal communication).

4.2.5.4 Coastal Environmental Considerations

At the present time the North Carolina Coastal Resources Commission (CRC), has not adopted regulations or policies that directly govern utilizing saltwater wetlands as part of wastewater systems. In the absence of such specific guidance on this subject, there is some wording found in the CRC general use standards that would affect the use of the coastal wetlands for projects such as this. In 15 NCAC 07H.0208(2)(A), the North Carolina Department of Natural Resources and Community Development is required to find "the location, design, and need for development, as well as the construction activities involved must be consistent with stated management objective." In addition, the CRC standards in (2)(B) state:

"Before receiving approval for location of a use or development within these Areas of Environmental Concern (AEC), the permitting authority shall find that no suitable alternative site or location outside of the AEC exists for the use or development and, further, that the applicant has selected a combination of sites and design that will have a minimum adverse impact upon the productivity and biologic integrity of coastland marshland, shellfish beds, submerged grass beds, spawning and nursery areas, important nesting and wintering sites for waterfowl and wildlife, and important natural erosion barriers (cypress fringes, marshes, clay soils)."

Also, (2)(E) states "development shall not measurably increase

siltation," and (2)(F) further states "development shall not create stagnant water bodies." These findings must be made prior to the issuance of any permit for development in North Carolina salt water (coastal wetlands). Any questions of potential environmental degradation would have to be satisfactorily addressed before a wetland wastewater disposal program could be considered for implementation.

4.2.5.5 Other Programs in North Carolina

In addition to the water quality programs described above, there are other state programs which could affect the implementation of discharges to saltwater wetlands. These programs include the state dredge and fill program and the Coastal Area Management Act (CAMA). The use of coastal wetlands for wastewater management would require permits from the North Carolina Coastal Resources Commission through the Office of Coastal Management if excavation, filling, or structures were proposed in any Coastal Wetlands Areas of Environmental Concern (AEC). The orientation of these programs, however, is toward development activities. In fact, there is a special exemption under the CAMA program for utility work including inspection, maintenance and repair of existing water and sewer lines. This exemption would not apply to new projects. If a treatment facility were proposed in association with a private development, full disclosure would be required for the adjacent high-ground development and CAMA permits issued for that work also (D. Small, personal communication).

North Carolina also has a mosquito control program that has been designated to reduce or eliminate standing water in saltwater wetlands. Any discharge to wetlands from wastewater treatment would have to be implemented within the standards of this program.

4.2.6 South Carolina

4.2.6.1 Water Quality Standards

South Carolina's Department of Health and Environmental Control (DHEC) has established four specific water quality classifications for tidal saltwater areas. These classifications include SAA--Outstanding Resource Waters; SA--Shellfishing Waters; SB--Primary Recreation Waters; and SC--Secondary Recreation and Fishing Waters (see Table 4.1-1). In each of these categories, water must be free from debris, settleable solids, toxic, corrosive or high temperature substances; and must meet certain maximum temperature standards. Further specific standards for dissolved oxygen, coliform bacteria, pH, temperature and turbidity have been established for each of the four classes of saltwater. In addition, no discharge of treated waste is permitted in SAA class waters (South Carolina Regulation 61-68, 1981).

DHEC recognizes that some waters may not be consistent with specific numeric criteria of a specified use classification because of natural conditions. The department may develop specific numeric criteria for these waters. The state also recognizes that waters vary in their ability to assimilate nutrient loadings. Therefore, specific nutrient standards may be developed on a case-by-case basis.

DHEC does recognize the distinct differences of wetland waters and does append the term swamp to certain water classifications. Specific water quality standards have not been developed for wetlands, however, and except for site-specific standards for pH, dissolved oxygen or nutrients, as mentioned above, it is likely that standards for water quality in saltwater wetlands would be the same as for the adjacent body of open water.

4.2.6.2 Discharge Permits

Wetlands are considered waters of the state and therefore any discharges to wetlands must be permitted by the DHEC. Wetland discharges are distinguished from other wastewater discharges and DHEC has developed a specific policy addressing the determination of wasteload allocations. The adopted policy recognizes the difficulties in defining average water quality conditions in wetlands and in predicting the assimilative capacity of these waters. When specific water quality data are not available to identify the impact of a wastewater discharge to any swamp waters, publicly owned treatment works (POTW's) must provide secondary treatment. Discharges other than from POTW's must provide best available treatment (BAT) as defined by DHEC. Where a site investigation indicates that a mathematical model can adequately describe the impact of a discharge on the wetland, such a model will be used in setting a wasteload allocation.

4.2.6.3 Construction Grants Program

The procedures in place in South Carolina for prioritizing and funding construction grants projects may affect the implementation of

projects proposing discharge to saltwater wetlands. Wetland discharge systems are considered fundable by DHEC, and they are ranked on the funding priority list in a manner similar to other projects.

The priority system used in South Carolina is designed to favor projects that would eliminate documented water quality problems from high volume discharges. One of the factors in the ranking formula, the water quality improvement factor (E Factor) could, in certain situations, encourage saltwater wetland discharges currently having use restrictions and currently receiving a wastewater discharge. The E Factor establishes the value of the project due to its impact on improving water quality. Different factors are assigned based on the type or classification of the waters which would be improved. The highest E Factor is awarded when the water quality improvement would eliminate use restrictions to saltwater estuaries, swamps or salt marshes.

It has not been determined if wetland discharge projects would be considered innovative and alternative (I&A) by DHEC. If a project were found to be I&A it would be ranked separately and funded from monies set aside for implementing innovative and alternative technologies. Such a project would receive no other preference.

4.2.6.4 Other Programs

The South Carolina Coastal Council is responsible for administering the permit requirement of State Act 123 which was enacted by the General Assembly of South Carolina in 1977. The Act provides for the protection

and enhancement of the state's coastal resources. The Coastal Council has direct state authority to deny or issue permits in the critical areas defined in the Act. These areas include all of the state's saltwater wetlands.

Under regulations adopted to implement the permit program, the Council coordinates issuance of permits with agencies which regulate the installation and operation of wastewater treatment facilities, septic tanks and landfills. Normal maintenance and repair of sewer facilities are exempted from Council permit requirements as is the discharge of treated effluent. However, the Council is responsible for review and comment on any discharges. Their concerns would center on possible wetland degradation which could involve commercially important shellfish, recreational fisheries and critical wildlife habitats.

The Council has developed certain standards applicable to wastewater facilities. These state that:

- . construction of lagoons or impoundments for wastewater treatment facilities in critical areas shall be denied unless it can be demonstrated that there will be no significant environmental impacts and no feasible alternative exists,
- . whenever feasible, construction and design shall be accomplished so that no effluent will be discharged into areas where shellfish and other marine resources would be affected,
- . critical areas, including coastal waters, tidelands, beaches and primary ocean front dunes, should be avoided. Unless no feasible alternative exists, structures other than pipelines and lift stations will not be permitted in critical areas, and

- . treatment facilities and discharge pipes should be located and designed so as not to have adverse impacts upon areas of significant use.

4.3 MAJOR INSTITUTIONAL ISSUES

Based on this review of the three major wastewater management programs and the work conducted as part of the Freshwater Wetlands EIS, several major institutional issues can be identified. The three major issues are the need for clear direction in wetlands wastewater management, the need to clarify regulatory definitions and the need to provide program specific guidance.

4.3.1 Need for Clear Direction In Wetlands Wastewater Management

The lack of clear EPA direction concerning the use of wetlands for wastewater management has resulted in considerable confusion. Some federal programs discourage the use of wetlands for wastewater management. Other federal programs actively promote the use of wetlands as a treatment alternative. These differences in approach indicate the need for EPA to develop and enunciate a coordinated program direction. EPA should indicate whether it is promoting, passively permitting or discouraging the use of wetlands for wastewater management and within what constraints. The Clean Water Act and associated regulations need to be consistently interpreted and program specific decisions made within the framework of this interpretation.

Because of a lack of a clearly established EPA policy in the area of wastewater management in wetlands, the standards, permitting and grants programs are not well coordinated and at times inconsistent with regard

to wetland discharges. The problems are evident at both the federal and state level. Because federal programs are largely being delegated to the states, close coordination between federal and state agencies responsible for administering wetlands discharges is essential. In addition, better coordination between federal agencies with wetlands responsibilities will be necessary if wetlands wastewater management is to be consistent with the goals and intent of the Clean Water Act.

4.3.2 Need to Clarify Regulatory Definitions

Several issues relate to the Clean Water Act definitions of wetlands as waters of the U.S. and of wastewater treatment systems. EPA's consolidated permit regulations (40 CFR 122.3, May 19, 1980) defined wetlands as waters of the U.S. These regulations also state that waste treatment systems (such as ponds and lagoons) are not waters of the U.S. (except where those waste treatment systems are, or were previously, waters of the U.S.). As noted in the regulations, the Act was not intended to license dischargers to freely use waters of the U.S. as waste treatment systems. These definitions made clear that treatment systems created in waters of the U.S. remained waters of the U.S.

On July 21, 1980, the definitions of waters of the U.S. was changed based on arguments that the definition was too broad. Several industry petitioners argued that the language of the regulations would require them to obtain permits for discharges into existing waste treatment systems, such as power plant ash ponds, which had been in existence for years and are impounded waters of the U.S. In many cases, EPA had issued

permits for discharges from, not into, these systems. EPA reviewed the issue and then suspended the language in question based on the impoundment-ash pond issue. The wetlands issue, as a result, became unclear. Until such time as the July 21, 1980, suspension is revised, current regulations state that wetlands are waters of the U.S. and waste treatment systems are not. This could be interpreted to mean that if wetlands are used for treatment they would lose their status as waters of the U.S.

Section 301(b)(1)(B) of the Act states that all discharges to waters of the U.S. shall achieve a minimum of secondary treatment. Further, Section 402(a)(1) of the Act states that the requirements of Sections 301, 302, 306, 307 and 308 of the Act must be met before a discharge to waters of the U.S. can be permitted. None of these citations specifically addresses wetlands being used for treatment of wastewater. The current definition of waters of the U.S. (with the July 21, 1980, suspension) could, therefore, be interpreted to mean that if waters of the U.S. are used for treatment, then secondary treatment would not be required nor must water quality standards be met. However, if wetlands are considered to provide assimilation and not treatment, secondary treatment would be required prior to discharge to wetlands.

Clarification of the regulations to address this issue appears warranted. Stemming from the current definition of wetlands as waters of the U.S., several important wetland/wastewater management questions arise. These questions include the following: (1) Can wetlands be used

to provide treatment? (2) Must control of the wetland be demonstrated by the discharger? (3) Where must water quality standards be met? (4) Where will the discharge be permitted? and (5) What components of the system are eligible for federal grant assistance (and at what level)?

The lack of state regulatory definitions of a wetland as compared to an estuary or to marine waters could also result in problems if water quality standards for the wetlands differ from standards for the estuary or marine waters. If standards for the wetland and the adjoining water body differ, then a specific boundary between the wetland and the adjoining water body needs to be defined. Otherwise, the set of standards (and the corresponding treatment requirements prior to discharge) that apply for specific discharge locations can not be determined.

4.3.3 Need for Program Specific Guidance

Regulations for EPA's three major wastewater management programs (Water Quality Standards, NPDES Permitting and Construction Grants) are designed for facilities discharging to free-flowing streams and rivers, lakes and estuaries. As a result, program guidelines are usually not applicable for wetlands wastewater management. Specific standards, permits and grants issues for which program guidelines would prove valuable are discussed below.

4.3.3.1 Water Quality Standards Program

As noted in the November 8, 1983, Water Quality Standards regulations (40 CFR Part 131), a water quality standard defines the water

quality goals established for a water body, or portion thereof, by designating the use or uses to be made of the water and by setting criteria necessary to protect those uses. Water quality standards should, wherever attainable, provide water quality for the protection and propagation of fish, shellfish and wildlife and for recreation in and on the water. Standards must also take into consideration their use and value for public water supplies and agricultural, industrial and other purposes including navigation.

In most states, water quality standards, uses and criteria for wetlands are those that are established for the adjacent free-flowing stream segments. Many of the standards criteria designed to protect uses of the streams are not appropriate for wetlands and some significant wetland requirements and functions are not addressed by stream standards. Providing for wetland uses in water quality standards could allow for more effective protection and use of the resource.

Specific elements of the standards program that should be clarified to consider wetland wastewater management alternatives include the following:

- . Wetland uses that are protected by the Clean Water Act,
- . Other beneficial wetland uses that could be considered in establishing standards,
- . Narrative or numeric water quality standards criteria to protect and maintain wetland uses, and

- . Procedures that can be applied in establishing use criteria. Generic and site-specific criteria and variances are approaches that could be used in establishing use criteria. The establishment of wetland use sub-categories, wetland sub-segments (within an existing stream segment), creating new wetland segments, seasonal uses and criteria, and narrative criteria are additional features that need to be considered.

The scientific basis for the clarification of these elements of the standards program also have not been developed.

4.3.3.2 NPDES Permit Program

Wastewater discharges from publicly-owned treatment works to waters of the U.S. must receive a minimum of secondary treatment or treatment necessary to meet applicable water quality standards. Where a wetland and its downstream water body have different standards (i.e., the downstream water body has more stringent discharge requirements than does the wetland) because of site-specific or generic wetland criteria, it is possible that the wetland could serve to provide additional treatment or assimilation. In such cases, NPDES permitting should consider this pollutant removal in determining whether downstream standards are met.

The following are the major permits issues related to wetland discharge alternatives that should be clarified:

- . Conditions under which technology-based or water quality-based effluent limits are appropriate for wetland wastewater management projects;

- . Techniques to establish water quality-based effluent limits for wetland alternatives;
- . Techniques to determine removals of pollutants in wetlands to meet downstream standards;
- . Guidance addressing the current and potential use of permit conditions to mitigate adverse impacts or respond to regulatory requirements; and
- . Options for monitoring locations and parameters to document attainment of established limits and/or standards.

4.3.3.3 Construction Grants Program

Wetlands used for wastewater management involve a range of construction grants issues related to the cost effectiveness analysis, ownership or control requirements, funding eligibility and level of federal funding. The resolution of many of these questions is related to the interpretation of the Clean Water Act and associated regulations. Further, planning aspects of the Construction Grants Program may be valuable to wastewater management agencies regardless of the availability of construction grants funding.

For a wetland discharge (regardless of any treatment provided), control, ability to use or ownership of the wetland must be demonstrated. Construction Grants 1982 (EPA's most recent publication of guidelines for the Construction Grants Program) states that a project will be evaluated to determine if the grantee/applicant has sufficient rights to the project land to ensure undisturbed construction and operation of the project for its useful life. Methods of obtaining these rights include fee simple title, easements, ownership of certain rights (e.g., those rights that could be detrimentally modified by the system), and leasing.

Questions related to liability, reasonable land costs, the area or extent of a wetland required, loss of the landowner's rights, applicability of Section 404 permits for the discharge of dredged and fill material, and impacts on multiple uses become more complex when privately owned wetlands are involved. The issue of control or ownership may determine implementability of the wastewater discharge in certain cases. For example, in North Carolina nearly all coastal wetlands below mean high water (MHW) would be considered to be owned by the state. Waters below MHW are used for navigation during high tide. Easements on property owned by the state are handled by the North Carolina Department of Administration. Irregularly flooded wetlands, however, can be privately owned.

If water quality standards in the wetland and downstream water body are appropriately assigned and if they are different (i.e., the downstream water body has stricter discharge requirements), the wetland could serve to provide additional treatment to achieve downstream standards while standards in the wetland are met. Conversely, if the standards for the wetland and the downstream water body are the same, further treatment by the wetland would not be required. Regardless of the degree of treatment provided by a wetland, recent direction (April 25, 1984) from Jack E. Ravan, EPA's Assistant Administrator for Water, does provide guidance on the issue of the eligibility of the purchase of wetlands under EPA's Construction Grants Program. In response to questions regarding the eligibility of the purchase of wetlands in a South Carolina project, it was determined that EPA funding is not available for the

costs of providing treatment beyond the permitted point of discharge to the wetland.

The following list summarizes the major construction grants issues related to wetland discharge alternatives that should be clarified:

- . The specific factors important in developing and evaluating wetlands alternatives (i.e., environmental review criteria, implementability, operability, reliability, flexibility, and energy requirements) that should be addressed;
- . Access or control requirements over a wetland used for wastewater management should be clarified; and
- . Funding eligibility, funding levels, applicability of IaA, etc. should be clarified.

4.3.3.4 Other Programs

Other program requirements and wetland protection procedures may apply to wetland discharges. The extent to which the other programs discussed in this chapter apply specifically to wastewater management in wetlands needs to be outlined.

4.4 LITERATURE CITED

- Alabama Water Improvement Commission. 1982. Regulations, policies and procedures. Title II Water quality criteria and use classifications. Montgomery, Alabama. 37 pp.
- Burke, R. August 1983. Personal communication. Georgia Environmental Protection Division.
- Department of the Army. Office of the Chief of Engineers. 1977. U.S. Army Corps of Engineers permit program: a guide for applicants. Washington, D.C. 20 pp.
- Department of Defense. Corps of Engineers. Department of the Army. 1975. Permits for activities in navigable waters or ocean waters. Federal Register 40(144). Washington, D.C. pp. 31320-31428.
- Department of Defense. Corps of Engineers. Department of the Army. 1979. Environmental quality: policy and procedures for implementing NEPA (33 CFR Part 230). Preliminary. Federal Register 44(127). Washington, D.C. pp. 38292-38316.
- Department of Defense. Corps of Engineers. Department of the Army. 1981. Environmental quality; Policy and procedures for implementing the National Environmental Policy Act (NEPA); Correction (33 CFR Part 230). Federal Register 46(40). Washington, D.C. pp. 14745-14746.
- Department of Defense. Corps of Engineers. Department of the Army. 1983. Proposed revisions to rules for dredge and fill permits under section 404 of Clean Water Act (48 FR 21466). Environment Reporter 14(3). Washington, D.C. pp. 108-118.
- Department of Defense. Corps of Engineers. Department of the Army. 1984. Proposed rule to amend permit regulations for controlling certain activities in waters of the United States. Federal Register 49(62). Washington, D.C. pp 12660-12664.
- Department of Defense. Corps of Engineers. Department of the Army. General regulatory policies; permit authority (33 CRF 320). Code of Federal Regulations. Washington, D.C. pp. 641-652.
- Department of Defense. Department of the Army. 1982. Environmental quality; environmental effects of Army actions (32 CRF Part 651). Federal Register 47(192). Washington, D.C. pp 43685- 44562.
- Federal Water Pollution Control Act, as Amended (The Clean Water Act). 1972 with 1977 and 1978 Amendments. Water Pollution Control Federation. Washington, D.C. 136 pp.

LITERATURE CITED (continued)

- Florida Department of Environmental Regulation. 1981. Florida Statutes. Chapter 403 Environmental Control. pp. 778-836.
- Florida Department of Environmental Regulation. 1981. Florida Statutes. Title XVIII Public Lands and Property, Chapter 235, State Lands. pp. 1432-1461.
- Florida Department of Environmental Regulation. 1982. Supplement to Florida Statutes 1981. Chapter 403, Environmental Control. pp. 501-514. Chapter 253, State Lands. p. 307-320.
- Florida Department of Environmental Regulation. 1983. F.A.C. Chapter 17.3. Water Quality Standards. Chapter 17-4. Permits.
- Garrett, W. 1983. Personal communication. Georgia Environmental Protection Division.
- Georgia Department of Natural Resources. Environmental Protection Division. July 1980. Water use classifications, trout stream designations and water quality standards for the surface waters of the state of Georgia. 29 pp.
- Grant, S.J. Jr. 1983. Personal communication. South Carolina Department of Health and Environmental Control.
- Heil, D. August 1983. Personal communication. Florida Department of Environmental Regulation.
- Johnson, M. August 1983. Personal communication. Georgia Environmental Protection Division.
- McIndoe, J. August 1983. Personal communication. Alabama Division of Environmental Management.
- Manasco, W. August 1983. Personal communication. Alabama Division of Environmental Management.
- Memorandum of Agreement between Alabama Department of Environmental Management and the Corps of Engineers relating to section 404 and section 10 permits. July 1983. 3 pp.
- Mississippi Department of Natural Resources, Bureau of Pollution Control. February 1982. Water quality criteria for intrastate, interstate and coastal waters. Jackson, Mississippi. 15 pp.
- National Marine Fisheries Service. 1983. Guidelines for proposed wetland alternations in the southeast region of the U.S. 13 pp.

LITERATURE CITED (continued)

- North Carolina Administrative Code. February 1983. Subchapter 7H - State guidelines for areas of environmental concern. Sections .0100 to 1000. pp.7-1 to 7-59.
- North Carolina Department of Natural and Economic Resources. Environmental Management Commission. 1979. North Carolina Administrative Code. Chapter 2 Environmental Management. Subchapter 2B Sections .0100 Procedures for assignment of water quality standards and .0200 Classifications applicable to surface waters of North Carolina. Raleigh, North Carolina. pp. 2-12 to 2-37.
- Olmstead, R. August 1983. Personal communication. National Shellfish Sanitary Program.
- Robertson, P. August 1983. Personal communication. South Carolina Department of Health and Environmental Control.
- Sansbury, C. July, August 1983. Personal communication. South Carolina Department of Health and Environmental Control.
- Schaenbaum, Thomas J. with Kenneth G. Sillman, research assistant. November 1976. Coastal planning: the designation and management of areas of critical environmental concern. A university of North Carolina Sea Grant College Publication. Raleigh, North Carolina. 31 pp and footnotes.
- Seyforth, R. August 1983. Personal communication. Mississippi Department of Natural Resources.
- Small, Daniel. September 1984. Personal Communication. North Carolina Department of Natural Resources and Community Development.
- South Carolina Coastal Council. 1981. Permitting rules and regulations. Chapter 30 Sections 48-39-10 to 48-39-230. Code of Laws of South Carolina. 49 pp.
- South Carolina Department of Health and Environmental Control. July 1981. Water classification standards system for the state of South Carolina. Regulation 61-68. 16 pp.
- State of Florida Department of Environmental Regulation. 1982. F.A.C. Chapter 17-25, Regulation of stormwater discharge.
- State of Florida Department of Natural Resources. Division of State Lands. Sovereignty submerged lands management, Rule No. 16Q-21 and correction sheet.

LITERATURE CITED (continued)

Sutton, Reg. August 1983. Personal communication. North Carolina Department of Natural Resources and Community Development.

Thabaraj, J. July 1983. Personal communication. Florida Department of Environmental Regulation.

U.S. Environmental Protection Agency, February 1983. Region IV Atlanta, Georgia. Wetlands Disposal of Treated Wastewater Environmental Impact Statement Phase I Report.

U.S. Fish and Wildlife Service. Fish and Wildlife Coordination (16 U.S.C. 661-667e). pp. 409-415.

Wahab, T.A. 1983. Personal communication. North Carolina Department of Natural Resources and Community Development.

Westall, F. July, August 1983. Personal communication. North Carolina Department of Natural Resources and Community Development.

5.0 SCIENTIFIC CONSIDERATIONS

Saltwater wetlands are characterized by physical and biotic factors working in dynamic equilibrium. Key components of these ecosystems include geomorphology, vegetation, hydrology, water quality and wildlife. The use of saltwater wetlands for municipal or seafood-processing wastewater management has the potential for both positive and negative impact. The purpose of this section is to identify and describe the major functions and processes of saltwater wetlands in the southeastern United States and to identify and assess the known or expected impacts related to wastewater management in these wetlands.

The formation of saltwater wetlands and the physical forces that continue to shape them are discussed in the opening section of this chapter. The distribution and species composition of wetland vegetation are dependent on the geomorphology of each wetland. Vegetation forms the base of the food chain for all organisms associated with this system. Regional characterization and tidal inundation are two of several factors discussed concerning the hydrology of wetlands. Water quality, a closely associated wetland component, is discussed with regard to natural conditions and potential changes resulting from wastewater discharges. Wildlife characteristic of saltwater wetlands, including threatened and endangered species, is described as the final saltwater wetland component. Scientific factors related to wastewater management in saltwater wetlands provide the summary section of this chapter.

5.1 GEOMORPHOLOGY

5.1.1 Estuaries

According to the generally-accepted definition of Pritchard (1967), an estuary is a semi-enclosed coastal body of water which has full connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage. River mouths, coastal bays and lagoons behind barrier islands are examples of estuaries. In the southeast, estuaries are either the mouths of drowned river valleys, bays or lagoons semi-isolated from the sea by barrier island formation, or some combination of the two. Eighty to ninety percent of the Atlantic and Gulf coasts consist of estuaries and lagoons (Emery, 1967), the remainder being headlands. Salt marshes are prominent geomorphic features of Southeastern estuaries.

The estuaries of today were formed in geologically recent (Holocene) time by the rising sea level which resulted from melting of the ice masses of the last period of global glaciation (Russell, 1967; Figure 5.1-1). Estimates of sea-level rise since the Quarternary Ice Age range from 450 to 800 feet. Estuarine development reached a peak when a sea-level stillstand was established about 3000 years ago (Russell, 1967; Figure 5.1-2).

Once formed, estuaries function naturally as traps for terrigenous sediments discharged by rivers, sediments eroded from the basin margin, and sediments moving along open beaches or onshore from the immediate offshore region (Guilcher, 1967; Mathews et al., 1980; Figure 5.1-3).

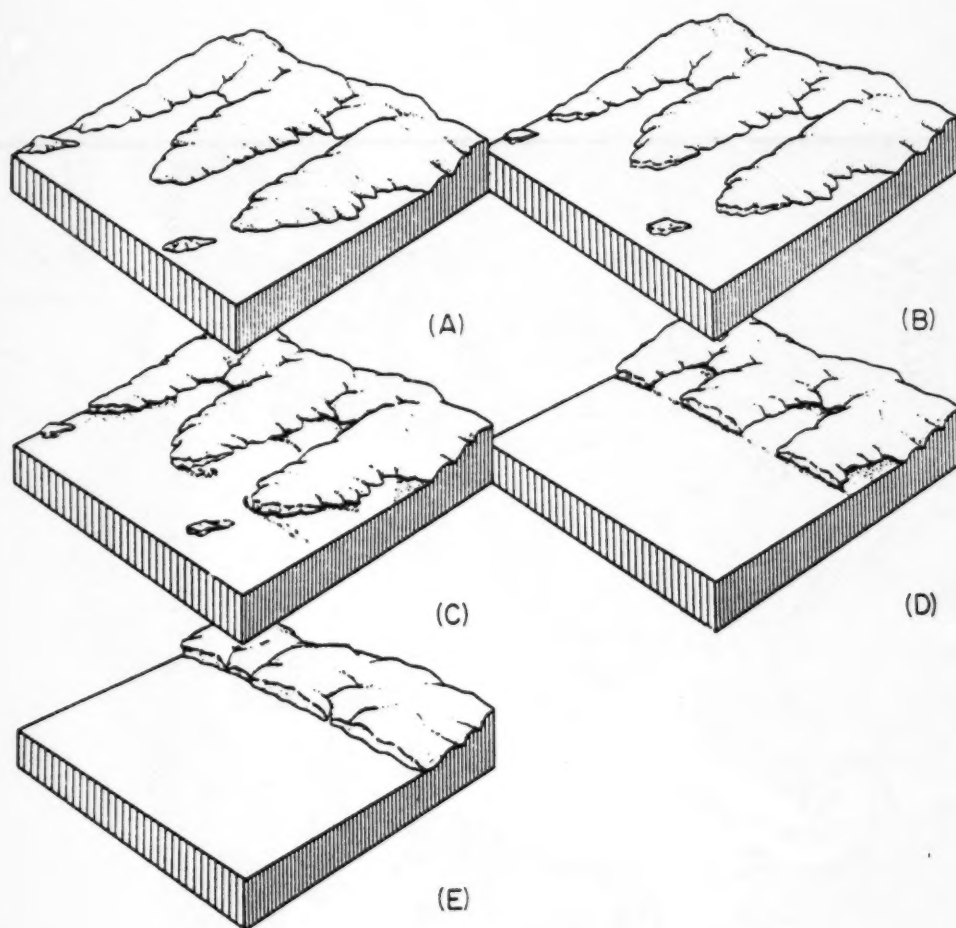


Figure 5.1-1. Development Stages in a Shoreline of Submergence. The initial stage (A), characterized by headlands projecting seaward, results from drowning of the lower reaches of stream valleys. In early youth (B), sea cliffs at the ends of the headlands are typically present. Depositional features, such as bayhead beaches and sandspits, are characteristic of late youth (C). In early maturity (D), the water between headlands has become somewhat enclosed by the formation of bayhead bars across the entrance resulting in the development of lagoons or "lakes." Continued erosion and filling of the lagoons results in the formation of a more regular shoreline lying back of the original headlands; this stage, essentially one of equilibrium, is termed full maturity. Source: Reid 1961

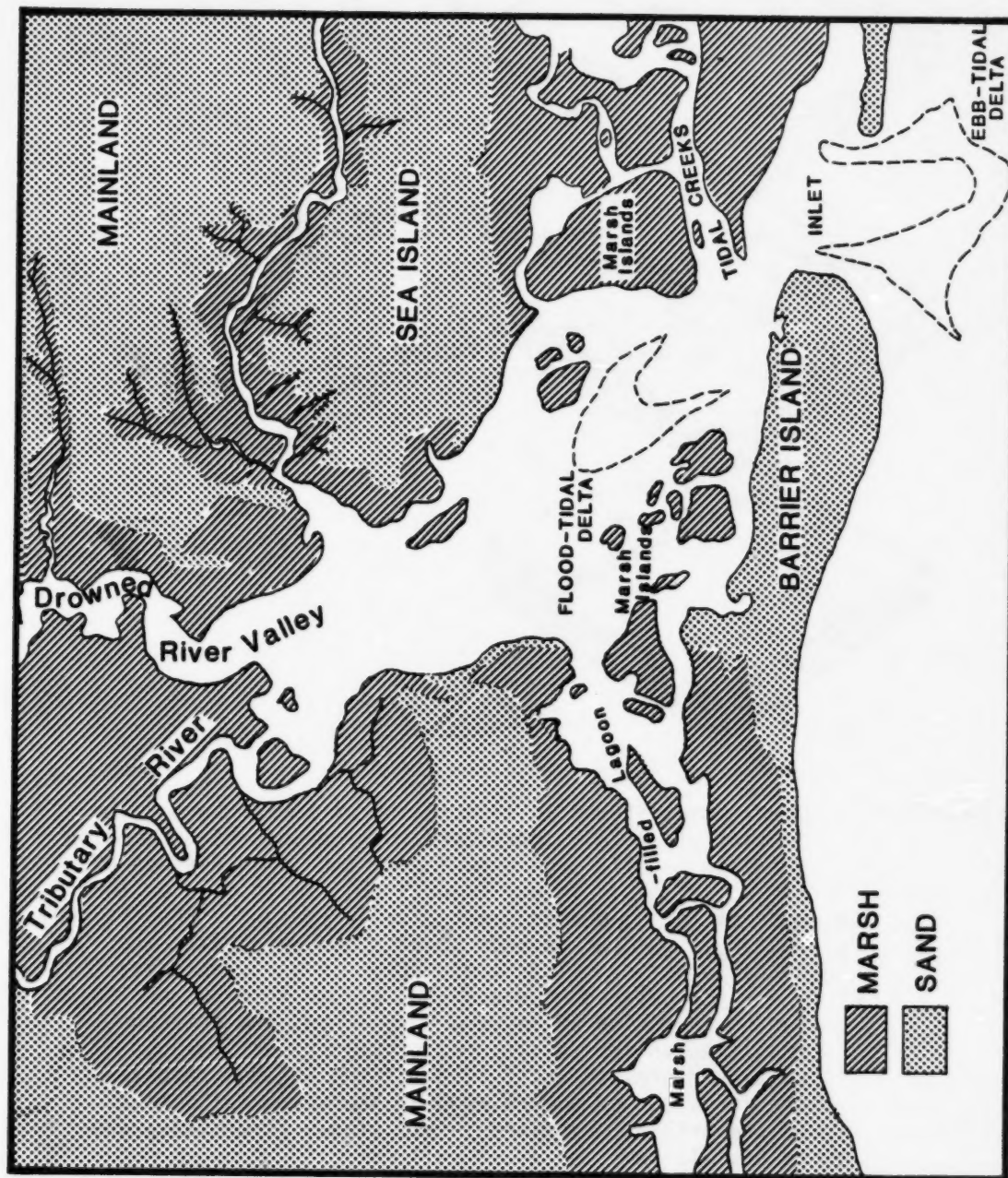


Figure 5.1-2. Generalized Well Developed Estuarine System.

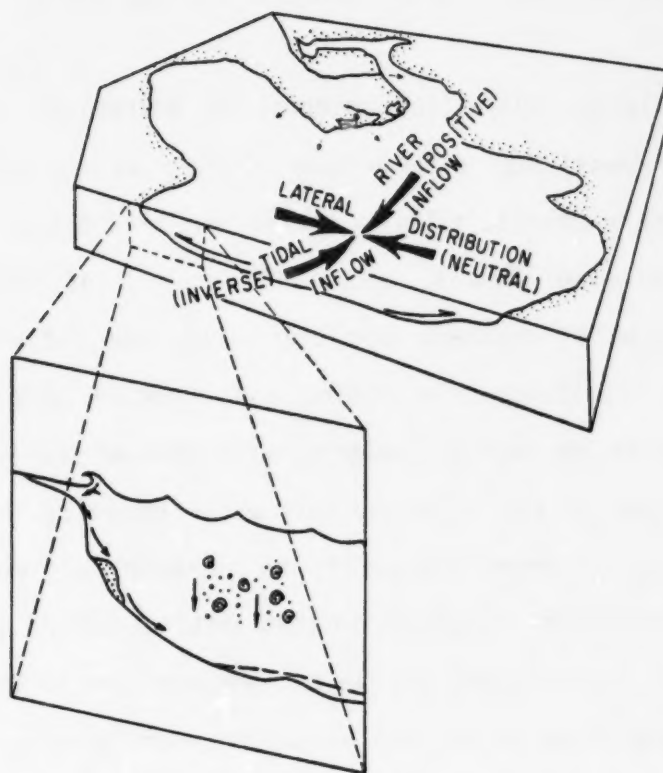


Figure 5.1-3. Schematic representation of estuarine dynamics showing river flow moving obliquely towards the viewer, tidal inlet flow moving obliquely away from the viewer during flood tide, and lateral distribution processes acting to disperse sediment throughout the basin. The enlarged section illustrates vertical accretion of suspended material and lateral distribution of previous deposits by shoreline erosion and redistribution. Basin sediments accumulate by positive-filling from rivers, inverse-filling from the sea by flood tides, and neutral-filling by self-digested materials eroded from the basin margin. Source: Rusnak, 1967

The existence within an estuary of an essentially closed circulation system for suspended sediments is due to the character of water movement. Water passes freely through an estuary yet sediments are trapped or, at least, are retarded in their movement (Postma, 1967).

Initially, clay-sized material is entrapped. During transport, these sediments may undergo many changes as a result of chemical or biological processes, salinity variations, presence or absence of vegetation, burrowing animals, etc. The process of flocculation and deflocculation of sediment particles under the influence of changes in salinity (resulting from ebbing and flooding tides) exerts a great influence on the settling velocity of suspended sediments. This process is conducted at the fresh and salt water interface (Postma, 1967). The end result of these changes is to increase sufficiently the size of suspended sediment particles so that settling occurs during slack water. Sediments in an estuary may be carried back and forth and deposited and eroded many times before they settle permanently.

Although some estuaries may be sandy, the typical deposits of most estuaries are fine-grained muds. Gradually, depositional areas of estuaries may build to such an extent that they become emergent on low tides and form intertidal flats. After deposition on these flats, sediment particles may adhere to mud surfaces and require relatively higher current velocities to resuspend them (Postma, 1967). This results in a net increase in the size of depositional areas over time and the gradual filling of the estuary over the course of many thousands of years.

5.1.2 Salt Marsh Ontogeny

Once tidal flats begin to be periodically exposed, they become potential sites for colonization by emergent vegetation such as Spartina or mangroves. The principal factors which interact to determine the development of the salt marsh appear to be the tidal range, the physiology of the plants inhabiting the intertidal areas, the process of sedimentation on open tidal flats and within the stands of plants, and the changing level of the sea relative to the land (Redfield, 1967).

In a study of a New England salt marsh, Redfield (1967) hypothesized that salt marsh development begins when a barren slope near the high-water level becomes vegetated by plants tolerant of limited submergence (i.e., high-marsh species), in this case Spartina patens, dwarf S. alterniflora and Distichlis spicata. As they decompose, these plants produce what is termed high-marsh peat. The intertidal slope becomes covered with tall S. alterniflora. The accumulation of sediment within the S. alterniflora stand builds up a layer of intertidal peat until the high-water level is reached. High-marsh species then succeed the intertidal species (Redfield, 1967).

If sea level rises after this process begins, the uplands bordering the estuary will become submerged and covered with a layer of high-marsh peat. If sediment is deposited in the intertidal area at a rate as great as or greater than the rise in sea level, then the intertidal marsh will grow out over the rising surface of the intertidal flat such that the lower limit of S. alterniflora retains its critical elevation relative to

the rising high-water level. Meanwhile, high-marsh peat will be deposited over the intertidal peat as far into the estuary as the intertidal marsh has built up to the high-water level. Therefore, a well-developed salt marsh will consist of high-marsh peat (covered with high-marsh vegetation) which increases in depth from the upland to the site of the original high water line and will be underlain by the surface of the submerged upland (Figure 5.1-4). Beyond that, the subsurface will usually consist of sedimentary deposits overlain by intertidal peat that slopes upward, away from the upland (Redfield, 1967). Over many years, the estuary is transformed into a marsh-filled lagoon (Figure 5.1-2).

5.1.3 Soils

Along the Gulf coast, salt marshes are built primarily upon deltaic-alluvial deposits created by the major river systems. Those of the south Atlantic region are built upon soft silt deposits which bridge the estuarine lagoons between the barrier islands and the mainland (de la Cruz, 1981).

Tidal-marsh soils are of Holocene origin and consist of sediment layers deposited over older, Pleistocene sand layers (Hoyt, 1968). Marsh sediments are composed of fine sand, clay and organic deposits in various percentages and large amounts of water. These soils are less permeable than upland soils. There are two layers in marsh sediments. The upper layer is aerated, leached and dark brown in color. The lower layer is black and rich in reduced compounds resulting from anaerobic decomposition of organic matter. These compounds are principally sulfides of

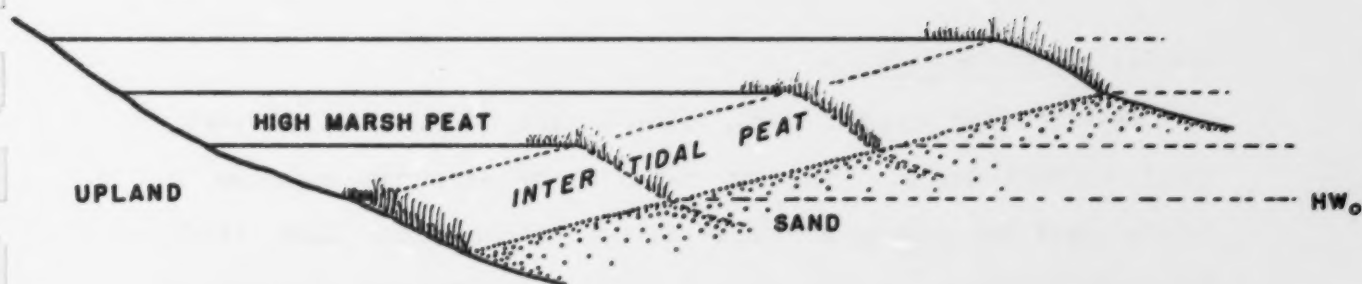


Figure 5.1-4. Development of a typical New England salt marsh with rising sea level and continued sedimentation. Source: Redfield, 1967

iron and other metals (Mathews et al., 1980). The pH of this anaerobic layer is neutral to slightly alkaline.

The combination of constantly water-saturated conditions and the presence of large amounts of organic soils (histosols) make salt marshes sites of nutrient and metal adsorption. Wastewater from sewage treatment or shellfish-processing facilities could be a significant source of nutrient input and, to a lesser extent, metals input (Section 5.4, Water Quality).

5.1.3.1 Nutrients in Soils

Besides being sediment traps, estuaries are also physical and biological nutrient traps. Nutrient recycling by estuarine organisms is fairly rapid and creates a kind of self-enriching system (Odum, 1971). This natural tendency toward eutrophication makes estuaries vulnerable to pollution because pollutants are trapped as readily as nutrients.

Nutrients are constantly exchanged between living and nonliving structural components of the ecosystem in nutrient or biogeochemical cycles. Each of these interdependent cycles has a relatively small "exchange pool" that is rapidly cycled between organisms and their immediate environment and a much larger, slow-moving, "reservoir pool" in the atmosphere (nitrogen cycle; Figure 5.1-5) or sediment (phosphorus cycle Figure 5.1-6).

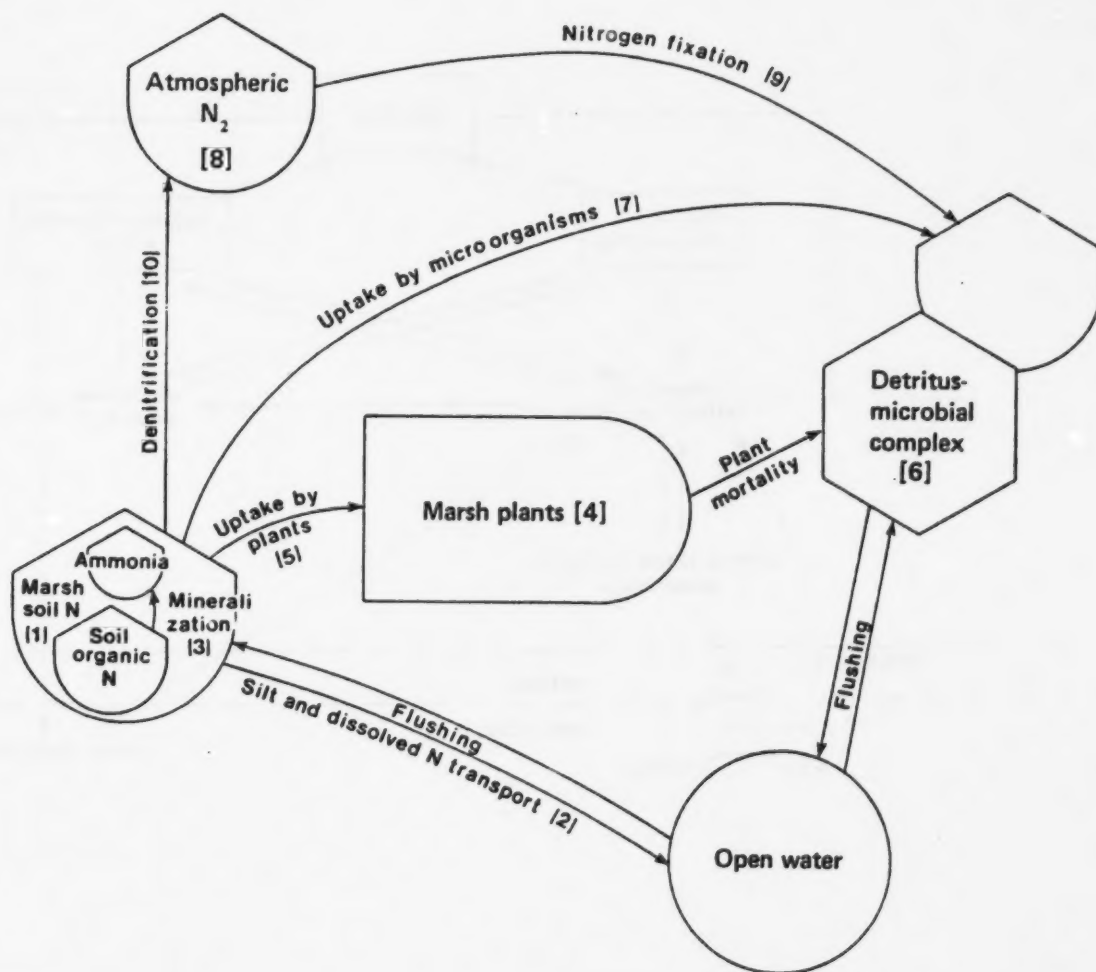


Figure 5.1-5. A model of the marsh nitrogen (N) cycle showing the major stores of N and interrelated processes. (Gosselink et al., 1979)

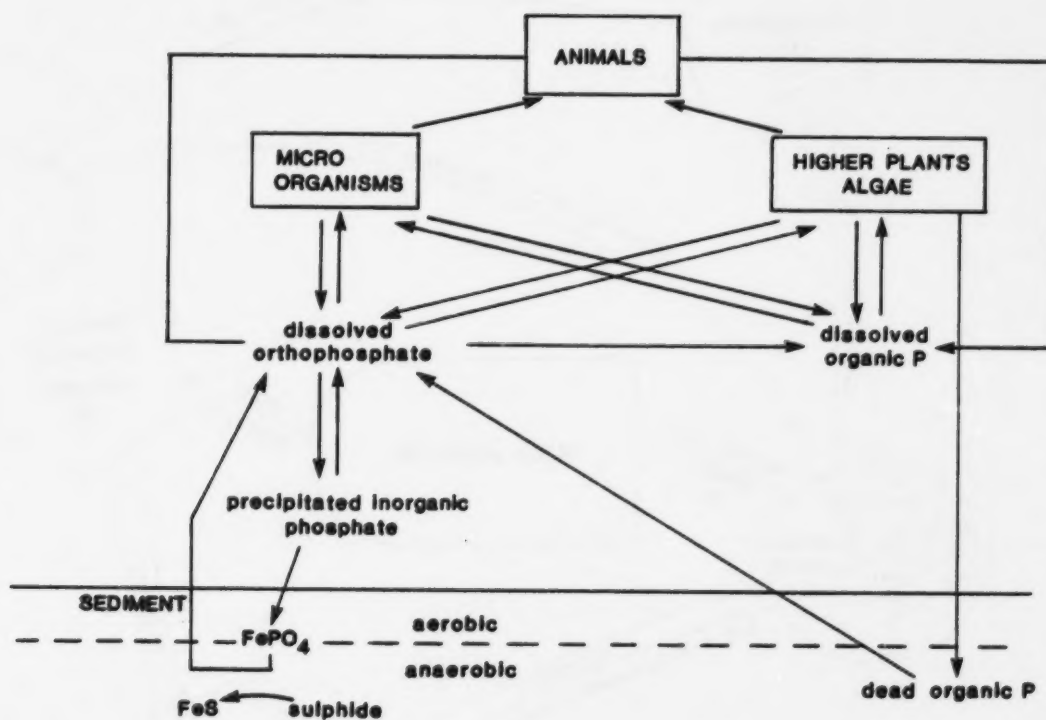


Figure 5.1-6. Phosphorus cycle in a salt marsh.
Source: Long and Mason, 1983.

The most common limiting materials in an ecosystem are carbon dioxide, which enters directly from the air, and inorganic nitrogen and phosphorus, which are taken up through the roots. Research has shown nitrogen to be the most limiting nutrient in a salt marsh (Gosselink et al., 1979). Phosphorus is usually the limiting nutrient in freshwater lakes and streams, and this may also be true of fresh and intermediate marsh habitats. Nichols's (1983) paper on the capacity of natural wetlands to remove nutrients from wastewater, it was stated that numerous wastewater slow-rate application studies (in freshwater areas) had shown that wastewater P did not move far in the soil but was retained near the surface. Soluble inorganic phosphate was readily immobilized in soils by adsorption and precipitation reactions with aluminum (Al), iron (Fe), calcium (Ca) and clay minerals. Phosphate reactions with Ca occurred under alkaline conditions, while reactions with Al and Fe predominated in acid to neutral soils. The chemical and physical adsorption of phosphate onto the surface of soil minerals is a rapid process, with much of the adsorption taking place within a few minutes. Other, slower reactions continue to remove phosphate from solution for periods of several days to several months (Nichols, 1983).

Because N exists in many forms (nitrates, nitrites, nitrogen oxides, ammonia), the N cycle in wetlands is far more complex than is the P cycle (Figures 5.1-5 and 5.1-6). Denitrification is the principal means of N removal, and denitrification is dependent upon the supply of available organic carbon. In (freshwater) wetland soils maintained under anaerobic conditions, Nichols (1983) reported that 90 percent of added NO_3^-

disappeared within a few days, either by denitrification alone or in concert with some other microbial immobilization. Under natural conditions, the rate of NO_3^- diffusion to the anaerobic portion of the sediment was often limiting. Nitrification of NH_4^+ to NO_3^- took place in the oxygenated surface layer of the soil. The NO_3^- then diffused through the aerobic layer to the anaerobic layer where it was denitrified.

Nichols (1983) further reported that, with increased loading rates, a wetland's efficiency of N or P removal from wastewater declined. With continued application, a P-saturation point was eventually reached in the wetland soil after which P could be released from the soil to the overlying water, if the water had a relatively lower P content. N removal did not decline over time since the supply of organic carbon, necessary for denitrification to take place, is virtually inexhaustible in a wetland. Nichols (1983) concluded that wetland vegetation could absorb large quantities of N and P during the growing season, but that much of it was released back to the water column when the plants died and decomposed. Additionally, it was concluded that wastewater application to natural wetlands was an effective method of nutrient removal only if wetland area was abundant and loading was low (e.g., one hectare of wetland needed to remove 50 percent of the N and P in wastewater produced by 60 people). Because higher N and P loading rates would be accompanied by higher hydraulic loadings, retention times in the marsh would be reduced and less time would be allowed for N and P removal reactions to occur. At very high loadings, N and P removal would be restricted to settling out of particulate forms (Nichols, 1983).

Denitrification is regulated by the supply of organic carbon. Odum et al. (1979) have hypothesized that specific tidal wetland areas may either export or import particulate organic carbon on an annual basis depending upon two geophysical factors: 1) the geomorphology of the wetland drainage basin and 2) the relative magnitudes of the tidal range and freshwater input from upland sources. Odum et al. (1979) stated that drainage basins connected to large water bodies by a narrow, shallow channel act as traps for organic material produced in and around the basin and also for organic matter brought in by incoming tides. These drainage basins have a net import of organic carbon. At the opposite extreme are V-shaped drainage basins which gradually deepen and widen toward the mouth. Such basins are net exporters of particulate carbon. Most estuaries have geomorphological characteristics intermediate between these extremes. In such cases, the relative strengths of tidal and freshwater inputs, along with other hydrological considerations, will control the annual net flux of particulate organic carbon (Odum et al., 1979).

5.1.3.2 Metals in Soils

When metals in a dissolved state reach aquatic systems, their behavior is governed by the rules of coordination chemistry (complex formation). Trace metals form associations with water molecules (hydration) or with organic molecules (chelation). The activity or mobilization of trace metals in aquatic systems is influenced by redox potential and pH, but activity is determined primarily by the stability of the element-complex (Brooks, 1977).

Trace metal concentration is divided among the free ionic forms, inorganic ion pairs, inorganic and organic complexes, inorganic and organic colloids, and living organisms and their remains. The concentration of each of these ionic forms changes continually and is affected by temperature, salinity, solubility, water hardness, chemical speciation, biological activity and other factors (Dvorak, 1978).

Within sediments, metals are associated with organic compounds or clay particles, both of which are abundant in estuarine salt marshes. Transport mechanisms for metals in rivers entering estuaries vary according to the type of metal transported, the type of substrates through which the river flows, and the sediment load of the river. Other components of fluvial matter are humic acids which are known to have strong metal-chelating capabilities (Dvorak, 1978).

The mobility of metals varies with environmental conditions (Table 5.1-1). In the neutral-to-alkaline, anaerobic soils of salt marshes, most metals are immobile or have very low mobility. Therefore, metals tend to accumulate in salt marsh and other estuarine sediments.

5.1.4 Assessment

Despite a salt marsh's geologically ephemeral nature, application of treated wastewater to salt marshes would have no effect on the formation of estuaries or the processes which create them. On a human timescale, however, there appear to be three geomorphologically-related areas of concern: 1) erosion, 2) accumulation of nutrients in marsh soils, and

TABLE 5.1-1
RELATIVE MOBILITIES OF SELECTED METALS IN AQUATIC SYSTEMS^a

Relative mobility	Environmental conditions			
	Oxidizing aerobic	Acid	Neutral to alkaline	Reducing anaerobic
Very high				
High	Zn	Zn, Cu, Ni, Hg		
Medium	Cu, Ni, Hg, Cd	Cd	Cd	
Low	Pb	Pb, Mn	Pb, Mn	Mn
Very low to immobile	Mn, Cr	Cr	Cr, Zn, Cu, Ni, Hg	Cr, Zn, Cu, Ni, Hg, Cd, Pb

^aSource: Dvorak (1978).

3) accumulation of metals in marsh soils. All of these concerns would be manifested after relatively long-term exposure of salt marshes to treated wastewater and would further contribute to an estuary's natural tendency toward eutrophication or pollution.

Erosion would be the most immediate and therefore most observable impact. In relatively sparse high marshes, erosion could be significant unless wastewater was applied at very low velocities or applied such that the velocity of water in established flow paths was not significantly increased. Materials eroded from the high marsh could impact the vegetation of the low marsh through sedimentation. Denser marshes would probably be able to sustain higher velocities before erosion took place. Conversely, nutrient-laden effluent could stimulate high-marsh plant growth to the extent that sediment eroded from upland areas would be trapped and deposited in the high-marsh. Over the course of time, the high-marsh vegetation would be overgrown with upland shrubs and other non-marsh vegetation, or, in other words, the natural filling-in of the estuary could be accelerated.

If the objective of wastewater management is merely disposal, it would probably be sufficient to apply treated wastewater to any area (high or low marsh) of a wetland. However, if the objective is additional treatment, application of wastewater must be restricted to the high marsh since the low marsh is subject to tidal inundation at regular intervals. Application to low-marsh areas for treatment purposes would be equivalent to direct discharge into the estuary since metals, nitrogen

forms and some phosphates would have insufficient time to be taken into the marsh soils or vegetation before the next tidal cycle. Although most phosphates are readily taken into marsh soils in a few minutes' time, they stay near the surface where they can be resuspended in the water column by flooding and ebbing tides or by reworking of the sediments by salt-marsh invertebrates. Exclusive use of high marshes would restrict the number of sites where treated wastewater could be applied to those areas having very extensive high marshes. In many places, however, particularly in the south Atlantic region, the high marsh exists only as a relatively narrow band surrounding more extensive low marshes. Additionally, even high marsh is subject to inundation on spring tides or storm tides. On such occasions, N and P uptake in dead vegetation would be released to estuarine waters along with any phosphates in the soil that were over and above the point of saturation.

Gulf coast marshes differ from south Atlantic marshes in several respects. First, because of higher productivity, more dead material accumulates in Gulf marshes than in south Atlantic marshes. Secondly, tides have less influence on the lateral movement and physical fragmentation of dead material on a day-to-day basis, because tides along the Gulf have less energy than those along the south Atlantic. Thirdly, flushing of Gulf marshes occurs in pulses over long periods of time. Summer southerly winds and storm tides provide the driving force in the net export of organic material. These factors result in longer exposure periods and calmer inundations of marsh areas, both of which facilitate nutrient deposition (de la Cruz, 1981). For this reason, wastewater

application may be more feasible in Gulf coast marshes than in south Atlantic marshes.

In summation, the geomorphology of marshes is such that most cases of treated wastewater application may need to be restricted to very low levels of loading on very large surface areas, preferably on Gulf coast marshes on wide-mouthed estuaries. Even then, however, there are insufficient data available to determine what constitutes a low-level application, how much surface area is adequate, and what are the uptake rates of N and P by salt-marsh vegetation. While analytical tools used to study estuarine characteristics seem adequate to detect impacts, estuarine characteristics (such as the relative strengths of river and tidal flows, depositional/erosional patterns, sediment budgets, tidal energy, soil characteristics, nutrient loading, etc.) may vary considerably from one estuary to the next, necessitating case-by-case baseline or operational monitoring studies.

5.2 VEGETATION

The major vegetation habitats found in the saltwater wetlands of the southeastern United States include salt and brackish marshes, mangrove-swamp forests and submerged aquatic grass beds. Of these, marshes and mangrove swamps are the habitat types directly relevant to the subject of wastewater discharges in saltwater wetlands. Aquatic grassbeds are marine or estuarine subtidal systems and are not defined as a terrestrial wetland habitat. Intertidal mud flats are often associated with the edges of marshes, but support no vascular plant communities. Grassbeds

and intertidal flats, however, may be affected by wastewater runoff following discharge into wetlands.

5.2.1 Marshes

The largest habitat-type by area found in the southeastern saltwater wetland environment is the marsh. Marshes are vegetated flats with minimal elevation in areas with a gentle coastal slope and low wave-action energy. These conditions are most often found in estuarine tidelands, the landward sides of barrier islands and along intracoastal water bodies protected by barrier islands.

5.2.1.1 Salt Marsh

Salt marshes are subject to periodic inundation and so the vegetation of a salt marsh is specifically adapted to this environmental stress. The salinity values found in a saltmarsh are high but vary with season and location. Soil salinities of 25 to 42 ppt have been reported from the Altamaha River delta of Georgia (Gallagher and Reimold, 1973; Gallagher et al., 1975), and marsh salinities of about 12 ppt have been recorded for the Louisiana Chenier Plain (Gosselink et al., 1979). A waterlogged, salt tolerant grassland grows under these conditions. This grassland is divided into low- and high-marsh zones.

The low-marsh zone is the area that extends from the water's edge at mean sea level inland to the mean high-water level. This area is dominated by smooth cordgrass (Spartina alterniflora), which grows in a tall form adjacent to the shoreline and in a shorter form at higher eleva-

tions. The high-marsh zone extends from the mean high-tide level inland to the limit of high spring and storm-tide inundation. Without the stress of regular tidal flooding, the high-marsh zone supports a more variable plant community dominated by black needlerush (Juncus roemerianus) and saltmeadow cordgrass (Spartina patens). Saltgrass (Distichlis spicata), sea oxeye (Borrchia frutescens), saltmarsh aster (Aster tenuifolius) and smooth cordgrass are also found as associated species in the high-marsh zone.

In some areas of the high-marsh zone, flats and depressions occur where saltwater can collect and evaporate. In these salt pannes or salt barrens, salinity is very high and a number of salt tolerant plants (halophytes) are found. Saltgrass and the succulent glassworts (Salicornia spp.) and saltwort (Batis martinima) are dominant in these locations.

As marsh elevation increases, a shift to upland vegetation occurs. A transitional zone is found, which may contain vegetation typical of a variety of hydrology and salinity regimes. The shrubs marsh elder (Iva frutescens), groundsel bush (Baccharis halimifolia) and wax myrtle (Myrica cerifera) are typical of this transition area.

The species and distribution of plants in a salt marsh are determined primarily by the depth and regularity of tidal flooding (Chapman, 1938; Hinde, 1954; Adams, 1963). The differing habitat preferences of smooth cordgrass and saltmeadow cordgrass illustrate the importance of

tidal level on vegetation distribution. Smooth cordgrass tolerates regular, deep saltwater flooding and, as a result, can form pure stands in the lowest saltmarsh zones. In contrast, saltmeadow cordgrass can tolerate full seawater on occasion but cannot withstand frequent submergence (O'Neil and Mettee, 1982). Thus, this species is found at higher elevations. Other factors such as soil type, nutrients, temperature, salinity, plant competition and human environmental alteration are also important to saltmarsh zonation (Penfound, 1952) but are not preeminent. The limited dominance of salt-tolerant species such as glassworts, saltworts and saltgrass in high-salinity salt barrens is an example of the localized effect of one such environmental variable.

In a biological sense, succession is the change in community structure from a simple system dominated by abiotic physical factors towards a system of greater biological diversity, maturity and stability. Each progressive stage in succession is supported by environmental modifications caused by pre-existing biological communities.

The vegetative succession in salt marshes occurs as a linear gradient away from the marine shoreline toward terrestrial upland. Whether the saltmarsh plant community is capable of modifying its surrounding environment over time by substrate deposition and stabilization is not clear. Marsh development may begin with the accumulation of sediment in a seagrass bed, which permits the colonization of smooth cordgrass. Further tidal sedimentation in the smooth cordgrass habitat would then allow the migration of black needlerush into the area. Saltgrass and

saltmeadow cordgrass growth would be the next step in a progression to the ultimate establishment of upland vegetation (Humm, 1973). This progression is hypothetical since no experimental evidence or long term observations are available. It has also been suggested that varying sea level, rather than biological environmental modification, is the dominant factor in saltmarsh succession (Adams, 1963).

A salt marsh is a pioneer community in a hostile physical environment and so biological diversity is low. Very few plants possess the adaptations such as salt tolerance, substrate stabilization and resistance to inundation needed to succeed in a saline wetland.

Although diversity is limited, biological productivity in salt marshes is high. Productivity values for salt marshes vary depending upon estimation techniques. Productivity values as high as 3773 g dry wt/m²/yr are cited for smooth cordgrass in coastal marshes of Georgia and South Carolina (Sandifer et al., 1980). Productivity values of this magnitude are comparable to those of agricultural lands managed for human utilization. However, a direct comparison of productivity values for dissimilar systems may not be appropriate (Humm, 1973).

Only a small part of marsh vegetation is directly consumed by wildlife. Most of the plant biomass produced in a marsh enters the detritus food chain (Odum and de la Cruz, 1967). Many chemical and physical processes break down marsh vegetation into smaller pieces that decomposing fungi, bacteria and microorganisms convert into a form usable

in higher food chains. The tidal flushing of this detritus makes the interface between marsh, tidal creek and estuary an important feeding area for shellfish and finfish that utilize detrital resources.

5.2.1.2 Brackish Marsh

Brackish marshes occur between coastal salt marshes and tidal freshwater wetlands and along estuarine shores where riverine fresh water mixes with marine salt water. Salinities in a brackish marsh range from about 10 ppt to 0.5 ppt. Vegetation zonation in brackish marshes is not as well defined as that in salt marshes because this habitat is a transitional one where plant species from both salt marsh and freshwater wetland habitats occur.

The zonation in a brackish marsh is primarily dependent upon salinity and not tidal inundation, as in salt marshes (Sandifer et al., 1980). The lower reaches of a brackish marsh are similar in appearance to a high salt marsh. Black needlerush is the dominant plant form, often occurring in dense stands, while a border zone of smooth cordgrass grows along river and stream edges. Other common species in this area include saltmeadow cordgrass, saltmarsh bulrush (Scirpus robustus) and three-square bulrush (Scirpus olneyi). In the upper reaches of a brackish marsh, giant cordgrass (Spartina cynosuroides) replaces needlerush as the dominant species. Common freshwater species that are mixed with saltmarsh species include sawgrass (Cladium jamaicense), arrowheads (Sagittaria spp.), spike rush (Eleocharis spp.), cattails (Typha spp.) and common cane (Phragmites australis).

The ecology of brackish and salt marshes are very similar. Both are characterized by tidal and estuarine import of sediments and nutrients to the plant community, a detrital food chain based on high primary productivity, and the dispersal of this detritus by tidal flushing. Productivity values for brackish marshes are high, although somewhat lower than those recorded for salt marshes. Values of 2,800 g dry wt/m²/yr have been reported (Gosselink et al., 1979).

5.2.1.3 Impacts to Marshes from Wastewater Discharges

The use of marsh habitats for wastewater management would rely upon the capacity of marsh vegetation to successfully utilize potentially high nutrient loads. Saltwater marshes have been considered for this use because of the high productivity of the dense vegetation that is found there. Also of importance to any discharge plan is the ability of the marsh vegetation matrix to physically hold, disperse and process wastewater discharges as influenced by the regular circulation and flushing that occur in tidal marshlands. A number of investigations have considered the application of sewage on marsh habitat. It has been suggested that the preferred utilization of marshes for wastewater management would be to provide advanced treatment without altering natural marsh drainage processes (Gosselink et al., 1974; Rabolais, 1980). The addition of sewage nutrients has been found to increase the biomass of marsh vegetation (Haines, 1979; Hardisky et al., 1983). Through nutrient assimilation by vegetation and sediments a marsh can lower the nutrient content of water passing through it to open water systems. The retention by experimental salt marsh plots of 80 to 90 percent nitrogen and 91 to

94 percent phosphorous nutrients applied as sewage sludge during summer months has been reported (Valiela et al., 1973). An annual nitrogen nutrient loading capacity for this system was estimated at 110 g/m^2 (Teal and Valiela, 1973). Long-term absorption capacity or year round seasonal retention were not reported in this case, however. An analysis of nutrient removal by freshwater wetlands cautions that much of the nutrient uptake by marsh vegetation is seasonally reversible, with eutrophication impacts occurring when winter dieback of plants takes place (Nichols, 1983). Because of this phenomenon and because of lowered vegetation growth and nutrient uptake in winter months, the discharge of wastewater should likely be reduced during winter.

Heavy metal uptake by marsh plants also has been reported (Lee et al., 1976; Giblin et al., 1980). Giblin et al. recorded elevated levels of cadmium, chromium, copper and zinc in marsh vegetation treated with sewage sludge. In this investigation marsh sediments retained 20 to 35 percent cadmium, 20 to 50 percent chromium, 60 to 100 percent copper, 55 to 100 percent lead, 80 to 100 percent iron, 55 to 60 percent manganese and 20 to 45 percent of the zinc added in sewage sludge over a two-year period. The metal loadings reported in this study were 490 mg/m^2 cadmium, $10,300 \text{ mg/m}^2$ chromium, $2,010 \text{ mg/m}^2$ copper, $110,000 \text{ mg/m}^2$ iron, $1,740 \text{ mg/m}^2$ lead, $1,320 \text{ mg/m}^2$ manganese and $6,820 \text{ mg/m}^2$ zinc over a two-year period.

In a report summarizing 12 years of experimental enrichment of a New England salt marsh, nutrients were found to be non-toxic to vegetation

when an annual nitrogen input of 225 g/m^2 and phosphorous (P_2O_5) input of 135 g/m^2 were employed (Valiela et al., 1982). Complex and long-term alteration in plant community composition have been observed during this investigation. Oscillating blooms and dieback of smooth cordgrass (a dominant marsh grass species) followed by surface denudation or replacement with other species such as saltwort, saltgrass or marsh hay cordgrass have been observed. Under the influence of continued nutrient enrichment the number of plant species growing in the marsh also has declined. These community changes were not judged by the investigators to be detrimental to the marsh ecosystem since these effects were simply shifts in vegetation proportions which could be naturally encountered in undisturbed salt marsh ecosystems.

Changes in salinity, caused by the application of freshwater sewage to salt and brackish marshes is another area of concern. In a study of high-salinity southern California marshes, it has been suggested that the continued addition of freshwater effluent could bring about a shift in vegetation community composition. Freshwater-marsh species could replace salt-marsh vegetation in areas that normally are hypersaline because of low freshwater input and high rates of evaporation (Zedler, 1982, 1983). In the southeastern United States, salt marsh and hypersaline salt barrens may be found in the vicinity of brackish and freshwater marshes. High annual rainfall and riverine freshwater input into estuarine wetlands cause this association of saline, brackish and freshwater marshes. The application of freshwater effluent to salt and brackish marshes could bring about the growth of vegetation typical of marshes with lower salinity levels.

A potentially positive impact from wastewater discharges to marsh habitats would be the recovery of hydrologically-depleted wetlands. The regular input of wastewater into marshes degraded by diking or canal drainage could help to reestablish these marshes. Diked areas deprived of natural tidal flow are habitats that could benefit from managed wastewater discharge (Zedler, 1982).

5.2.2 Mangrove Swamps

Mangrove swamps are found in coastal areas subject to periodic flooding with saline or brackish water. The plant species found in a mangrove swamp are facultative halophytes, tolerant of, but not requiring a saltwater environment. They are limited to saltwater wetlands because of the reduced competition from other vegetation. Mangroves possess specialized root and reproductive structures adapted to inundation and loose, wet soils. Three species dominate the mangrove community: red mangrove (Rhizophora mangle), black mangrove (Avicennia germinans) and white mangrove (Laguncularia racemosa). Buttonwood (Conocarpus erectus) is an associated shrub species found in saltwater swamps but is not considered a true mangrove. In the southeastern United States, red mangrove and white mangrove are limited to peninsular Florida, while black mangrove is concentrated in peninsular Florida with scattered occurrences along the northern coast of the Gulf of Mexico.

Within the swamp-mangrove ecosystem, six community types have been described (Lugo and Snedaker, 1974). Overwash forests occur on islands where regular tidal flooding takes place. Fringe forests occur as a

relatively narrow edge along shorelines that are somewhat higher than average high tide. Riverine forests are found along estuarine rivers and creeks where regular tidal flooding occurs. Very tall mangrove growth occurs in this community. Basin forests occur in depressions that carry inland terrestrial runoff toward the coast. This community type is found near the coastline and is affected by daily tidal flow. Hammock forests are found on slightly elevated areas with minimal tidal influence. Scrub forests are made up of mature yet stunted specimens and occur in areas where substrate and nutrient limitations lead to curtailed growth; these areas are limited to the flat coastal edge of south Florida.

There has been uncertainty with regard to the zonation and succession of mangrove ecosystems. Early investigations proposed that mangroves acted as coastline "land builders", exhibiting a linear zonation/succession from coastal pioneer habitat toward upland-terrestrial tropical forest (Davis, 1940). In a more thorough, recent presentation, Odum et al. (1982) contend that mangrove populations are cyclic-climax systems influenced periodically by hurricane, fire or drought/hypersalinity. Mangroves were described as being capable of land maintenance or stabilization but sea level fluctuation was deemed to be the overriding factor controlling coastline contour. Species zonation in mangrove communities is complex, involving factors of tidal amplitude, salinity, substrate, interspecific competition and environmental perturbation. A very generalized interpretation of mangrove growth would place red mangrove as dominant in the lower elevations between mean low tide and mean high tide. White and black mangroves, which are very salt

tolerant, are dominant at higher elevations where evaporation of infrequent tides causes high-salinity conditions. In less saline inland areas, buttonwood is also found as a component of mangrove communities.

Like salt marshes, mangrove swamps support a substantial detrital food chain. Branch and leaf litter are broken down by various physical, chemical and biological processes. Fine detritus particles are transported out of the swamp forest by tidal movement. The primary productivity of the mangrove ecosystem that supports this detrital food chain is very high, perhaps even higher than that of salt marshes. Odum et al. (1982) present estimates of mangrove primary productivity as high as 12.6 grams carbon/m²/day (gC/m²/day). Productivity values expressed as grams carbon reflects biomass as approximately 30 to 40 percent of dry weight productivity values.

The feasibility of wastewater discharges has not been investigated for mangrove swamps. It is possible that mangrove swamps could successfully absorb treated wastewater because these swamps are periodically flushed and very productive. Further investigation of this topic is needed at this time, however.

5.2.3 Aquatic Grassbeds

Seagrasses are marine flowering plants that form extensive subtidal beds on sand and clay substrates. Along the coast of Florida, Alabama and Mississippi three species are commonly found: shoal grass (Halodule wrightii), turtle grass (Thalassia testudinum) and manatee grass

(Syringodium filiforme). Three species of Halophila are less commonly encountered. Widgeon grass (Ruppia maritima) is also found as an associate of seagrass beds in estuarine areas of lowered salinity. This species is actually a freshwater plant with marked salinity tolerance. Eel grass (Zostera marina) is a temperate marine species that is found along the Atlantic coast from Canada to North Carolina. Eel grass may occur as far south as north Florida but is not found in the Gulf of Mexico.

It has been hypothesized that seagrass habitats are a primary-successional stage leading to salt-marsh establishment (Humm, 1973) or perhaps to mangrove swamps. Seagrass beds are highly productive systems; total community productivity rates of 16 g dry wt/m²/day have been reported (Zieman, 1982). Seagrass beds may show enhanced production with moderate sewage-nutrient enrichment but cannot withstand prolonged contact with concentrated wastewater (Zieman, 1982). In such situations, excess epiphytic algal growth on seagrass leaves, competition with macroalgae or diminished light penetration, caused by high-nutrient levels, decreases grassbed coverage.

In brackish to freshwater estuarine aquatic habitats, a variety of non-marine submerged flowering plants are found. Fanwort (Cabomba caroliniana), mares tail (Myriophyllum spp.), horned pondweed (Zannichellia palustris), pondweed (Potamogeton spp.), water nymph (Najas guadalupensis) and the nuisance species, Eurasian water-milfoil (Myriophyllum spicatum), are included in this group. Turbidity and increased nutrient levels associated with human development and com-

petition with other species have resulted in diminished grassbed coverage and community diversity in many areas (Zieman, 1982).

5.2.4 Intertidal Flats

Intertidal flats are often found as fringe areas around marsh habitats. Intertidal mud and sand flats occur in shallow, open saltwater areas where tidal fluctuation brings about cyclic exposure and inundation. These conditions prevent the establishment of vascular plant communities, but primary productivity from surface algal growth does occur. The main biotic feature of this habitat is a benthic community that plays an important role in the detritus food chain of coastal wetlands.

5.2.5 Summary

The saltwater wetland habitats found in the southeastern United States include salt and brackish marshes, mangrove swamps, aquatic grassbeds and intertidal mud flats. Marshes and mangrove swamps are the terrestrial wetlands of primary interest in this consideration of wastewater discharge. Aquatic grassbeds and intertidal mudflats are habitats associated with saltwater terrestrial wetlands which may be affected by wastewater runoff.

Both salt and brackish marshes are highly productive, tidally-flooded grasslands which support an estuarine food chain based upon substantial detritus export. Marsh sediments and vegetation have the observed ability to absorb sewage nutrients. At the loading rates

described in experimental studies, no toxic effects on vegetation from metals or nutrients have been found. Plant productivity has been found to increase with sewage nutrient applications. However, if wetlands were mowed to remove increased vegetation biomass, a change in species composition would be expected. A shift from tall marsh grasses to the shorter salt grass (Distichlis spicata) might cause a concomitant increase in the mosquito population that prefers salt grass habitat over other wetland species.

A number of unresolved issues requiring further investigation include: the long-term capacity of marsh sediments to absorb nutrients; the consequences of estuarine eutrophication following nutrient release by dead, wastewater-fertilized marsh vegetation; the fate of metals exported from the marsh through physical washout of unabsorbed wastewater, sediment release, incorporation of metals in vegetation detritus or release from dead vegetation.

Mangrove swamps are comparable to salt and brackish marshes in that they also are highly productive, detritus exporting systems influenced by tidal circulation. At this point no experimental findings are available concerning the discharge of wastewater into mangrove systems. Seagrass beds and intertidal mud flats are not suitable for wastewater discharge since they are aquatic systems with no capacity for effluent retention and processing.

5.3 HYDROLOGY

Saltwater wetlands are an integral part of the nearshore and estuarine ecosystems along the southeastern Atlantic and Gulf coasts.

Hydrologically, they perform many of the same functions as freshwater wetlands such as flood storage and storm-flow modification, water-quality alteration and erosion control. However, another aspect of major importance is their function as a nutrient source and salinity stabilizer for estuaries. Consideration of the hydrologic characteristics of these wetlands is of prime importance in understanding and evaluating their natural function in the ecosystem and the effects of any alterations caused by utilization as receiving areas for treated wastewater.

Characterization of saltwater wetlands is usually linked to biological aspects, such as growth patterns and species present. Most of these characteristics, however, are related to hydrologic considerations. Saltwater wetlands within Region IV can generally be divided into two groups, those occurring along the Atlantic coast of North Carolina, South Carolina, Georgia, and Florida and those occurring along the Gulf coasts of Florida, Alabama and Mississippi. This grouping is based primarily upon the differences in coastal energy, tidal heights and tidal periods between these two major sections.

Saltwater wetlands, in many respects, have the same hydrologic characteristics as freshwater wetlands. They are subject to, and controlled to some extent by climatic fluctuations, morphological variances, antecedent moisture and infiltration characteristics of their soils, ground water and man-made impoundments. To some extent, saltwater wetlands reduce peak discharges and total storm flow from rivers, reduce coastal erosion, provide quiescent settling areas for sediment deposition, and provide filtering and biological transformation of waters moving through the system.

5.3.1 Regional Characterization

A general relationship exists between the development of saltwater wetlands and characteristic coastal energy level. The higher the energy level, which is determined by a combination of tide and wave height, the more extensive the formation of tidal marshes that occurs. Figure 5.3-1 shows the general coastal energy levels for the study area as determined by comparing average annual tide and wave heights. As can be seen, the Atlantic coast has a higher overall energy level than the Gulf coast, and wetland development varies accordingly.

The most developed salt marsh systems in the United States are found along the Atlantic coast areas of South Carolina, Georgia and a small portion of northern Florida (de la Cruz, 1981). North Carolina's saltwater wetlands are characteristic of sheltered provinces because of the extensive offshore barrier islands. Wetlands in south Florida are characterized by localized marshes around waterways and river outlets, changing to larger mangrove and salt-marsh areas rounding the southern tip of the state.

Atlantic coastal marshes in the study area were formed on estuarine and lagoonal deposits that filled in between barrier islands and the primary shoreline. These marshes are low and regularly flooded due to the tidal domination of the coast. Numerous dendritic creeks and deeper tidal channels develop that have a significant effect on the hydrologic characteristic of the marsh. Tides are semidiurnal, and direct inundation by high salinity sea water makes these marshes true salt marshes, as compared to the more brackish Gulf marshes (de la Cruz, 1981).



Figure 5.3-1. Coastal Energy Levels. Source: Linton, 1968

Gulf coastal marshes are generally developed upon alluvial deposits in deltaic formations. They are irregularly flooded and are low-salinity marshes. Tides vary but, generally, they are weak and diurnal. The Gulf coast is classified as wave dominated because of the relatively lower tidal rise. The effects of freshwater rivers are greater in these wetlands than for the south Atlantic coastal wetlands.

5.3.2 Hydrologic Budgeting

Hydrologic budgeting is a method whereby an attempt is made to subdivide the total movement of water into and out of an area into its various components. Theoretically, the components can be measured and analysis can then be performed to evaluate the effects of increasing or decreasing the individual components. The following can be used to represent a budget for a saltwater wetland:

$$P + Q_i + G_i + T_i + \Delta s = ET + Q_o T_o + G_o$$

P represents precipitation, Q_i is fresh surface-water inflow, G_i is groundwater inflow, T_i is tidal inflow, and Δs is the change in storage. ET represents losses due to evapotranspiration, $Q_o T_o$ is combined fresh surface water and tidal outflow, and G_o is groundwater outflow. Actual measurement of these components, particularly groundwater flow and tidal flow, would not be easy. Additionally, groundwater flows may be dependent on tides, in that groundwater levels vary with the tidal cycle and hence groundwater flow may also vary.

The greatest effect on the hydrology of saltwater wetlands is due to variations in tidal frequency, duration and depth. Surface freshwater flow into wetlands may be significant in some cases, however, tides dominate over freshwater flow in the southeastern Atlantic and Gulf coastal areas. Generally, wetlands do not provide significant groundwater recharge (Gresson et al., 1978). Groundwater flow within or out of a salt marsh is difficult to ascertain and must be addressed on a case-by-case basis. Evapotranspiration also may exert a significant effect on the hydrologic budget of wetlands during some periods of the tidal cycle and with varying seasons.

5.3.2.1 Precipitation

Precipitation is one of the more easily measured quantities in the hydrologic budget. Precipitation values should be considered for specific sites under consideration for wastewater discharges. Overall precipitation amount varies with season, being generally greater in the winter, and is generally predictable. Precipitation falling on saltwater wetlands is not intercepted by vegetation cover because, unlike many freshwater wetlands, the leaves of most of the vegetation in saltwater wetlands are vertically oriented. Therefore, precipitation is not reduced significantly by interception, temporary storage or evaporation from vegetation.

The primary hydrologic effect of direct precipitation is to increase soil saturation between tidal inundations, possibly resulting in longer water retention due to lowered infiltration capability and loss of

available storage. Additionally, precipitation may alter surface salinity, pH and add some nutrients to the wetland ecosystem.

5.3.2.2 Surface Water (Fresh)

While water runoff, river inflow and tidal inflow are all surface water phenomena, freshwater inflow and tidal inflow come from two distinctly separate sources and are unrelated occurrences.

Surface freshwater inflow to a saltwater wetland will vary considerably depending upon the specific site. Great influxes of fresh water into an estuary may drastically alter the fresh and saline regimes which, in turn, may alter the biologic functioning of the estuary. In this respect, saltwater wetlands act to dampen the surge of freshwater flooding by providing temporary storage. In addition, greater increases in turbidity within the estuary may be avoided by quiescent settling of flood-carried sediments within the wetland.

In the south Atlantic region, runoff is bimodal, with a large peak in the spring and a smaller one in late summer. Run-off along the coast between Cape Romain, South Carolina and Fernandina Beach, Florida varies from 1 to 5 cubic kilometers per month. Eighty percent of the total flow can be attributed to the Pee Dee, Cooper-Santee, Savannah and Altamaha Rivers (Blanton and Atkinson, 1978). Only the Savannah River is considered to have a major influence on salinity levels in the associated wetlands and estuary (de la Cruz, 1981).

The Gulf coast wetlands, particularly in the northern coastal area, are influenced by freshwater inflow. Salinity is generally lower, in the brackish level of 2 to 15 parts per thousand, due to the influences of the Mississippi, Pearl, Pascagoula, Biloxi, Bay St. Louis, Mobile and Apalachicola Bay River systems. Influx of fresh surface water varies seasonally, areally and annually throughout this region.

The discharge volume of rivers emptying into saltwater wetlands is the primary consideration for estimating the areal extent of influence on the wetland area. If the tidal volume is greater than the river discharge, the river influence will be secondary to tides. This is the case for most wetlands in the northern Gulf and southeastern Atlantic coast. Therefore, while river influx may cause salinity alterations to some saltwater wetlands, tidal influences remain the dominant hydrologic effect (Gosselink et al., 1979).

5.3.2.3 Surface Water (Saline)

By far, the greatest overall hydrologic effect on most saltwater wetlands is tidally-induced saltwater flooding. The range and period of tidal flooding produces most of the physical and biological characteristics associated with salt marshes and wetlands and is the prime hydrological consideration for evaluating wetlands for wastewater management.

The south Atlantic region has a semidiurnal tide ranging from less than 1 to 3 meters and is characterized by a few major storm surges.

Tidal flooding peaks in some wetlands may be delayed from actual coastal high tides due to the influence of offshore barrier islands. This is particularly characteristic of wetlands in North Carolina.

Tidal amplitudes and flow periods affect the salinity levels and type of vegetation occurring in the intertidal zone. Flow periods also govern the frequency of wetland soil saturation and detritus and nutrient flushing, which would be of concern when considering detention time in wastewater management practices.

Gulf coast tidal variations are more complex than those on the Atlantic coast. Generally, Gulf tides are diurnal with a range of about 0.3 meters. Sometimes very weak semidiurnal or mixed tides may occur and tides may be changed in both time and occurrence of highs and lows by meteorological conditions. These conditions are generally seasonal. Strong summer winds pile up water along the northern Gulf coast, raising levels in bayous, bays and canals and frequently inundating wetlands. In winter, strong, northerly winds depress the tidal level as low as 0.5 meters below normal, draining marshes for long periods of time (de la Cruz, 1981). In addition, Gulf coast wetlands are subject to many high-energy storms in June through October that may remove considerable amounts of detritus and nutrients from the wetlands.

The export of sediment and nutrients to estuaries as the result of tides varies considerably with season and location. Net export may occur in summer, winter or during both of these seasons (Smalley and Thien,

1976; Ward, 1979; Valiela et al., 1978). Therefore, site-specific studies would need to be conducted to determine seasonal hydrologic parameters that may affect the flushing of nutrients from wastewater effluent into the estuary.

5.3.2.4 Groundwater

Groundwater also influences hydrologic interactions in saltwater wetlands. However, this aspect of the overall water budget may not be as significant, compared to river and tidal flows, as it is for many freshwater wetlands. This will have to be determined for each site considered for a wastewater discharge. Most soils in saltwater wetlands are comprised of fine clays and organic materials that do not allow for rapid infiltration of water. The greater the depth of mud and silt, the higher the impedance to water transport. This situation can generally be expected in older marshes.

The overall elevation of a marsh influences the height of the soil water table (Chapman, 1974). Therefore, lower marshes will not only be inundated more frequently but the soil water table level will occur closer to the surface. In addition to soil type, the percent of saturation of marsh soil will significantly affect the ability of the soil to absorb water (allow infiltration) and, consequently, aid in the drainage of water following inundation. Lower elevation marshes with organic and clay soil, therefore, would be subject to greater tidal runoff than higher marshes with more porous soils. This runoff would remove nutrients and detritus and result in pockets of standing water (Chapman,

1974). These water pockets may have little or no dissolved oxygen, which enhances anaerobic conditions in the underlying soils and ties up nutrients so they cannot be used by vegetation. Pathogens remaining in wastewater applied on the wetlands may also concentrate in this standing water.

Saltwater wetlands usually are not recharge areas for groundwater aquifers, functioning more often as discharge areas. Groundwater hydrology studies would have to be conducted to determine groundwater flow patterns for specific wetlands under consideration as receiving areas.

5.3.2.5 Evapotranspiration

Evapotranspiration can be estimated for various densities and types of vegetative growth by using specific wetland and climatic characteristics, including relative humidity, insolation, winds, free-water level, soil saturation depth and water table. Evapotranspiration aids in the removal of wetland standing water formed between tidal cycles, reduces the saturation level of marsh soils thereby increasing subsequent storage ability, and is a primary reason for soil salinity being above the salinity of the estuarine waters. Soil salinity is important because it affects the type of vegetation that can be grown in the marsh soils.

5.3.3 Inundation

The duration, depth and frequency of inundation in saltwater wetlands are primary factors in the distribution of nutrients, removal of organic detritus and composition of the biota. Inundation is also a

prime consideration for the evaluation of a specific wetland as a discharge site for wastewater, because inundation frequency, extent and duration have a great effect on effluent detention time within the wetland. Inundation is usually the result of tidal action, but peak-flood inundation may periodically occur in saltwater wetlands bordering rivers.

As discussed in Section 5.3.1, inundation frequency varies considerably throughout the study area. South Atlantic wetlands are inundated more predictably and consistently than Gulf coast wetlands, where greater variability would be expected.

An understanding of the tidal inundation cycle and its hydrologic effects within a saltwater wetland is important for evaluating the possible effects imposed by the addition of wastewater effluent. Chapman (1974) detailed the general processes of tidal inflow and outflow from saltwater marshes. During low tide, tidal waters are absent from the creeks and channels in the salt marsh. Most of the flow will be remnant drainage water, freshwater runoff and fresh water from underground springs, if any. As the tidal inflow begins, and this may be some hours after the coastal high tide, lateral seepage may occur from the creeks and channels into the marsh soil if the creek level exceeds the groundwater level. The rate of seepage will depend in large part on the type of exposed strata, such as sand, clay, mud or peat. In order for seepage to occur, gases trapped in the soils must be displaced. This does not readily occur through fine clay and organic soils and, therefore, back

pressures may limit lateral seepage. Lateral seepage during this stage of tidal inflow also will be affected by the distance from the creek, the volume of the creek and the height of the marsh. Once the height of the tide exceeds the height of the marsh, flooding will occur by sheet flow across the surface. From this point on, the increased height of tide will increase the area of marsh covered and will determine the depth of flooding within the marsh. Figure 5.3-2 summarizes the various flow steps during the tidal cycle.

As the tide begins to ebb, the reverse situation occurs. First, the majority of the surface water departs by way of sheet flow into the creeks and canals. This carries nutrients out of the marsh and into the estuary and promotes erosion of the creek banks as water pours over the edges. Any irregularities in the ground level of the wetland will cause shallow pools to be left behind. This remaining water is removed by infiltration and evapotranspiration, as discussed previously. Higher tide frequency results in higher soil saturation levels and longer retention time for pools.

Following periods of flooding, any infiltration into the marsh soil causes the water table to rise. The rate of this rise varies with the distance from drainage creeks and channels and the hydraulic conductivity of the soil. Once the creek level has dropped below the groundwater level, outflow of ground water may occur. Specific geologic areas within the marsh also may act as drainage conduits for localized portions of the marsh, including those composed of sand, peat or shingles. Their pre-

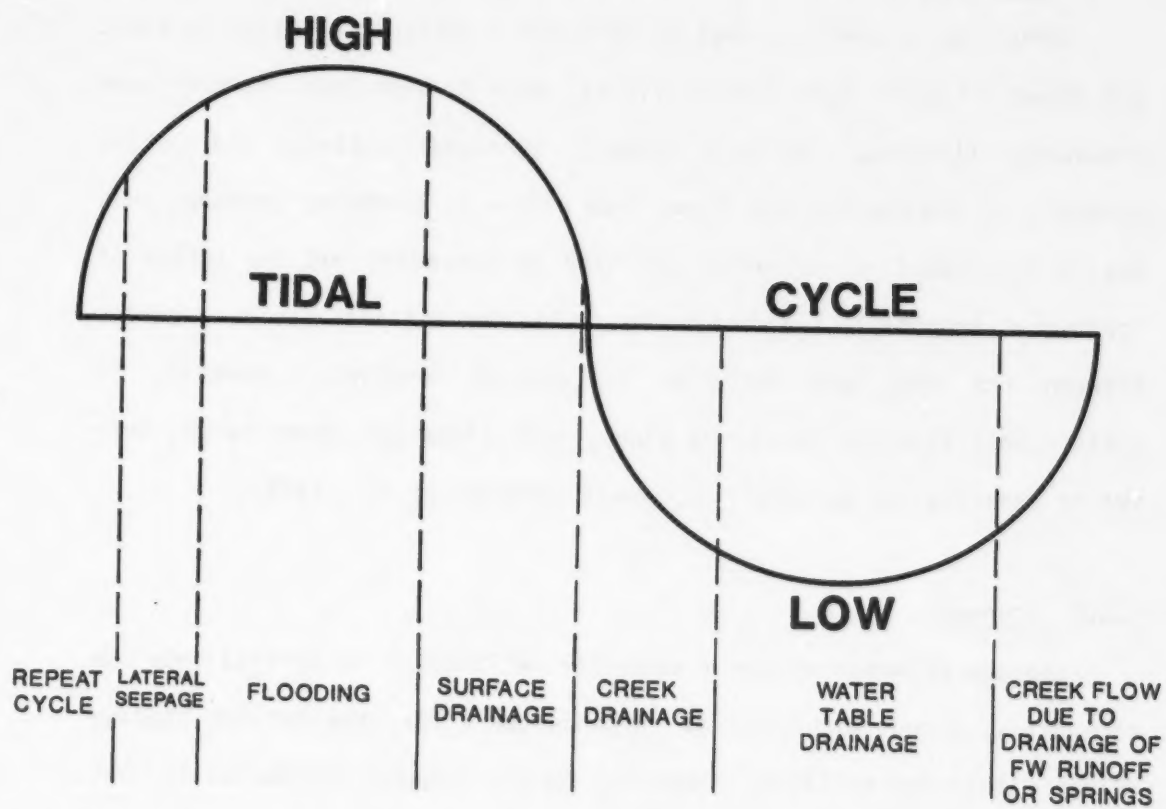


Figure 5.3-2. Wetland Water movement during Tidal Cycle.

sence in a proposed wastewater discharge site must also be considered when evaluating detention time and short circuiting potential.

5.3.4 Buffering

Buffering is the term used to describe a wetland's ability to limit the effect of major hydrological events, such as high seas, rainfall and freshwater flooding. In this respect, saltwater wetlands aid in the reduction of freshwater peak flows from rivers by temporary storage, thus easing the impact on estuarine salinity by spreading out the influx of freshwater temporally. Additionally, saltwater wetlands act as a buffer between the seas and shoreline to prevent erosion. However, in catastrophic flooding caused by winds, high tides and storm surge, buffering capacity may be relatively small (Greeson et al., 1978).

5.3.5 Storage

Storage of water within a saltwater wetland can be divided into two categories, ground and surface. Groundwater offers the largest storage volume within the wetlands. However, due to frequent inundation in most areas of consideration, available excess storage is usually limited. During periods of excess dryness, such as may occur in Gulf coastal areas in the winter, groundwater storage may provide the major source of water for marsh vegetation. Surface storage is generally very temporary. Storage of precipitation, river or tidal inflow can only be accomplished in pools created by irregularities in the surface or in the channels and creeks running through the marsh.

5.3.6 Hydraulic Loading

Hydraulic loading is the physical volume of water that can be applied to a wetland by natural fluctuations of tide, precipitation and rivers. This factor is dependent upon site-specific characteristics. The type of vegetation found in a salt marsh is generally determined by the frequency, duration and depth of flooding. Some plants may survive under hydraulic loadings greater than that which occurs naturally. However, specific limits have not been accurately established for vegetation associated with saltwater marshes, and a change in the makeup of biota may follow a change in hydraulic loading. Characteristics to consider in the evaluation of wastewater discharges should include the effects of increased hydraulic loading on vegetation and animal life and the impact of increased soil saturation periods, increased runoff and decreased storage capacity. Additional discussion of hydraulic loading is included in Section 6.0 of this report.

5.3.7 Impacts From Wastewater Effluent Application

Saltwater wetlands have evolved naturally to an equilibrium point based upon the amount of water and nutrients available, frequency and duration of inundation and soil moisture characteristics. Alterations to any of these parameters may cause a change in the biological and physical characteristics of the marsh. Whether these changes would be detrimental or beneficial would depend upon the specific characteristics of the site under consideration.

Some impacts which may be associated with wastewater discharges to wetlands include alteration of vegetation types as a result of continual saturation of the surface, increased erosion and detritus removal from runoff, or possibly decreased erosion due to increased vegetative growth as a result of increased nutrient availability. Seasonal variations in wetness and dryness within the wetland may be altered by the continual application of wastewater effluent. Additionally, anaerobic conditions in marsh soils may be exacerbated by the continual inundation by a layer of oxygen-depleted water. Anaerobic conditions may limit the availability of soil nutrients for biological use. Additionally, the application of wastewater may alter the salinity of water on the marsh, in marsh soils, and eventually in the receiving estuary.

5.4 WATER QUALITY

Maintaining water quality in wetlands receiving wastewater involves many components of the wetland system. Water quality changes occur as a result of geomorphological, hydrological and biological activities. The many complex interrelationships within a saltwater wetland ecosystem make the evaluation of specific water-quality impacts a difficult task, since other components are always involved. Consequently the following sections discuss water quality in terms of the relation of surface water to other components of the saltwater wetland and their dynamic interactions. The available data on wetland water quality is largely quantitative and site specific; thus conditions in one saltwater wetland do not exactly match conditions in another wetland.

5.4.1 General Water-Quality Parameters

Many water-quality parameters need to be considered when characterizing a saltwater wetland. Dissolved oxygen (DO), salinity, hydrogen-ion concentration (pH), suspended solids (turbidity), organic load (seston), water color, oxygen-demanding substances (BOD, COD), viruses and bacteria, and refractory (stable, persistent) chemicals such as metal oxides and pesticides are all important factors when evaluating the addition of wastewater effluent to coastal wetlands. Several of these parameters are discussed below to help characterize natural salt-marsh and mangrove habitats. Nutrients and heavy metals are discussed in Section 5.4.2.

5.4.1.1 Salt Marsh Characteristics

Dissolved Oxygen

Salt marshes are characterized by anaerobic (without oxygen) conditions in the sediments, particularly just beneath the surface of the substrate. Microbial activity at the marsh's surface leads to a rapid consumption of oxygen. In addition, regular tidal flooding of marshes can leave water in the interstitial sediment spaces, thus decreasing the rate at which gaseous oxygen can permeate the soil (Teal and Teal, 1969). However, sediment oxidation can occur through the release of organic oxidants by plant (Spartina) root systems (Valiela et al., unpublished). Sediments associated with Spartina roots, therefore, are more oxidized than bare sediments. Additional aeration of sediments could result from animal activity, such as sorting of the sediments by detritus-feeders (e.g. the crab Uca) or burrowing of crabs.

Surface waters flooding coastal-marsh sediments, particularly in tidal areas, are usually more oxygenated than sediments. Turbulence caused by changing tides can increase the dissolved oxygen in the marsh. However, much of the dissolved oxygen added to the marsh surface during tidal flooding is offset by the high rate of oxygen consumption at the surface (Teal and Teal, 1969). Superimposed on this tidal cycle of dissolved oxygen is a diel cycle. Photosynthesis produces oxygen in vegetated marshes during daylight hours. Studies of the Tinicum Marsh, near Philadelphia, have shown that the oxygen content of water was increased by filtering through the marsh (Horwitz, 1978). In the evening, when photosynthesis subsides and plants consume oxygen, DO levels in coastal marshes are reduced. Tidal flow from oxygenated estuaries, however, helps to offset reduced DO levels, and cooler evening temperatures allow for slightly greater oxygen saturation.

The saturation level of dissolved oxygen is highly dependent on temperature and salinity. Saturation values are low, for example, when temperature and salinity values are high. Dissolved oxygen values also may vary with water depth, generally decreasing with depth.

The amount of dissolved oxygen in the sediments and surface waters of coastal marshes is an important factor in determining the potential of salt marshes to assimilate wastes. The biotic community and microbial decomposition that occur in the marsh are partially dependent upon the availability of dissolved oxygen. The fresh water of the effluent theoretically could hold more dissolved oxygen than could the more saline

water of the salt marsh. In addition, any turbulence created during application of the effluent could effect a slight localized increase in the amount of dissolved oxygen in the marsh. However, the addition of wastewater to saltwater wetlands presumably would increase the biological and chemical demands for oxygen, thus further decreasing the dissolved oxygen available to the marsh community. The effect of the wastewater upon dissolved oxygen in the marsh, and subsequently upon the marsh flora and fauna, would be dependent upon the content of the wastewater and the area of the wetland receiving the effluent.

Salinity

Saline surface waters are characteristic of coastal marshes, although some inland marshes also may be somewhat saline. Coastal marshes of estuarine and marine systems can be described as hyperhaline (>40 ppt), euhaline (30.0-40 ppt), mixohaline/ brackish (0.5-30 ppt), polyhaline (18.0-30 ppt), mesohaline (5.0-18 ppt), oligohaline (0.5-5 ppt) or fresh (<0.5 ppt; Cowardin et al., 1979). Factors such as frequency and degree of tidal inundation, freshwater input from precipitation or tidal creeks, and drainage related to topography (e.g. pools or salt pannes left in higher saltmarsh areas) can result in salinity variations over time and at different locations within a salt marsh. For example, the salinity range for surface and sediment waters in a Delaware marsh was greater for bare bank and panne areas. These areas were not covered by leafy vegetation and thus had greater rates of evaporation, resulting in higher salinities (Sullivan, 1971). Salinity influences the distribution of marsh vegetation, such as Spartina grasses (see Section 5.2.1) and animals (Daiber, 1977) within the marsh.

The addition of freshwater-diluted sewage into a salt marsh would reduce the salinity somewhat. Seafood-processing effluent would have a similar effect, unless the effluent itself included brine and other saline waters used in seafood processing (see Figure 6.2-2 and Table 6.2-2). Depending upon the degree of salinity change, the effluent could cause changes in the chemical associations and reactions within the marsh. For example, the metal cadmium forms chloro-complexes at higher salinities, thus decreasing the free ion concentration of the metal and decreasing its subsequent toxicity (Engel et al., 1981). Salinity-related chemical changes also could affect the floral and faunal structure of the marsh over time. Freshwater irrigation of short Spartina alterniflora in a Delaware salt marsh resulted in significantly greater live leaf production and an extension of the growing season (Hardiskey et al., 1983). The authors proposed that the freshwater created "a more positive soil osmotic potential and increased soil water movement", resulting in a "potentially greater uptake of existing interstitial nitrogen by the plants." Thus, the fresher water of wastewater effluent might facilitate the uptake of some nutrients by salt-marsh plants.

pH

Dissolved salts buffer marsh surface waters so that the pH values are generally in the neutral range. The pH levels in sediments can vary from acidic to alkaline, depending upon the location within the marsh, time of day, season, and degree of tidal inundation. Sediment pH values in the Great Sippewissett Marsh in Massachusetts, for example, varied between 5 and 6.5 (Giblin et al., 1980).

In the Canary Creek marsh in Delaware, pH measurements were taken at five different saltmarsh areas (tall Spartina alterniflora, bare bank, dwarf or short S. alterniflora, Distichlis spicata, and panne) over a 12-month period (Gallagher, 1971). The pH of surface water in the five areas was generally neutral to slightly alkaline, with an annual range of 7.25-9.15. The annual range for pH of the sediment surface at all five areas was 6.25-9.00; pH of the sediment surface was neutral to slightly alkaline in all areas except in the short S. alterniflora, where pH was slightly acidic to neutral. The highest pH values for both surface water and sediment surface were found in the panne in August. A high pH of surface water in the marsh was associated with high algal activity on the mud surface (Sullivan, 1971). Sediment pH increased with depth in the tall S. alterniflora area but usually decreased with depth in the panne. In the Mission Bay marsh in California, the pH of sediment water varied from 6.8-8.3 (Phleger, 1977). The pH varied depending upon the time of day and the tidal stage in areas subject to tidal inundation. However, the monthly mean pH was near neutral. In the four different microhabitats tested within the marsh, the pH of sediment water was shown to decrease with depth. The relatively high pH (7.2-9.5) of salt marsh sediments studied in the Netherlands was related to the high carbonate content of the sediments and availability of ions through tidal flooding (Beefink et al., 1977).

The pH levels found in a salt marsh play an important role in the dynamic processes occurring within the marsh. The pH of surface water or sediments can be an indicator of chemical reactions occurring within a

salt marsh. For example, microbiological processes can convert organic sulfur or sulfate into hydrogen sulfide (H_2S) in the anaerobic saltmarsh sediments. If the sediments are aerated, the H_2S can be oxidized to sulfuric acid (H_2SO_4), which results in an acidic pH at the sediment surface. In the presence of carbonates or of ions brought into the marsh by tidal action, the H_2SO_4 can be converted to gypsum ($CaSO_4$), yielding a more neutral pH (Beefink et al., 1977). Gooch (1968) discussed the relationship of pH of saltmarsh water and seasonal cycles of both anaerobic microbial sulfide production and availability of dissolved phosphate in a Delaware marsh. In addition, the more acidic sediment of short Spartina alterniflora areas results in more phosphate going into solution and being available for uptake by algae and higher plants (Daiber, 1972).

The pH level of most domestic wastewater is neutral and well buffered, while that of seafood-processing effluent may be slightly alkaline (see Table 6.2-2). The effects wastewater has on the pH of saltwater wetlands depend on the volume of wastewater discharged and the buffering capacity of the wetland. A well-buffered wetland system tends to maintain a constant pH.

Turbidity

Turbidity in coastal marshes is caused by biological and physical factors such as plankton, land runoff, suspended organics and sediment, pollutants, and humic and tannic acids. Often, however, the primary source of turbidity is detritus that has been broken down by microorganisms (Gulf South Research Institute, 1977). Tidal flow can reduce tur-

bidity by transferring detritus to the estuary, but it also may contribute to turbidity by importing turbid or polluted waters and by causing turbulence that resuspends sediment particulates.

Wastewater effluent could add to the turbidity of water in the marsh if it contains an appreciable concentration of suspended solids or creates turbulence (i.e. resuspends detritus, sediment) during its introduction into the marsh. Increased nutrient levels from wastewater effluent also could increase turbidity by increasing productivity of plankton populations.

5.4.1.2 Mangrove Community Characteristics

Surface waters in mangrove communities can be characterized by salinity values ranging from near fresh to 40 ppt; DO levels between 2 and 4 ppm or near zero in stagnant areas or in areas of runoff; low total phosphorus values; moderate nitrogen levels (0.5 to 1.5 mg/l); total organic carbon (TOC) ranging from 4 to 50 ppm or higher; dissolved organic carbon (DOC) as high as 110 ppm; turbidity within 1 to 15 Jackson Turbidity Units (JTU); and pH (in Florida swamps) between 6.5 and 8.0 with alkalinity between 100 to 300 mg/l (Odum et al., 1982). These values are approximate and can vary with natural and human perturbations.

Although the specific effects of wastewater addition to mangrove communities are not known, changes in water quality might be similar to those discussed for salt marshes (Sections 5.4.1.1 and 5.4.2) and would be dependent upon the natural characteristics of the particular mangrove community under consideration.

5.4.2 Nutrient Removal and Metal Uptake

Application of secondary-treated wastewater to saltwater wetlands is a process that is gaining attention as a potentially economical, energy efficient method of nutrient removal compared to the cost of advanced wastewater treatment plants (Gosselink et al., 1974). However, economics is only one consideration when evaluating saltwater wetlands for wastewater management. The mobility, absorption/adsorption and translocation of heavy metals and pesticides also must be considered since marsh-estuary systems recycle nutrients through many food chains.

Few studies have been conducted to determine the effects of nutrient additions to saltwater wetlands through the application of wastewater effluent. Studies conducted by Teal and Valiela (1973) and others have demonstrated that salt marshes are capable of removing nutrients such as nitrogen from applied secondary-sewage sludge. Although the present assessment is not concerned with sludge disposal and sludge cannot be discharged to a wetland system because of their designation as "waters of the United States", the referenced examples of sewage-sludge applications are helpful in exploring the potential for saltwater wetlands to utilize sewage nutrients. At the same time, one must keep in mind that the physio-chemical and microbial composition of secondary-sewage sludge differs from that of wastewater effluent, so that the availability of nutrients in wastewater may differ from that in sludge.

5.4.2.1 Nutrients

Nutrients basic to living organisms are nitrogen, phosphorus, sulfur and carbon (USEPA, 1983). While Section 5.1.3.1 describes these nutrients in soils, this Section is relevant to the discharge of effluent into saltwater wetlands and water quality. The discussion focuses on two of the more essential nutrients, nitrogen and phosphorus. Of these two essential nutrients, nitrogen is usually the limiting nutrient in salt marshes (Valiela et al., 1973). The fine-grained organic muds of salt marshes usually contain sufficient amounts of other nutrients supplied by the tides and trapped in the mud (Teal and Valiela, 1973).

Nitrogen

Nitrogen in wetlands is present as inorganic (NH_4 , NO_2 , NO_3), gaseous (NH_3 , N_2 and N oxides) and numerous organic forms (Nichols, 1983). Nitrogen is used or removed from marshes through 1) tidal nutrient export ("outwelling"; Odum, 1971), 2) plant uptake primarily from sediments, 3) bacterial and algal fixation and 4) anaerobic bacterial denitrification (Teal and Valiela, 1973; Nichols, 1983). The consequences of these processes, respectively, are 1) estuarine nourishment with nutrients and detritus, 2) increased plant production, 3) formation of chemically-bound nitrogen (nutrient form) from nitrogen gas and 4) production of gaseous nitrogen from nitrate, which is utilized as an oxygen substitute under anaerobic conditions. Sources of nitrogen are the atmosphere through nitrogen fixation and estuaries and/or rivers that supply nitrogen through tidal or river currents. Nitrogen fixation ceases in the presence of adequate nitrogen (Teal and Valiela, 1973) that

can be supplied by tides, rivers or other non-atmospheric sources. Marsh vegetation can, therefore, apparently survive through periods of low nitrogen availability through nitrogen fixation, but forego the nitrogen fixation process and utilize nitrogen when available from natural external sources.

Experiments involving the artificial fertilization of salt marshes with commercial secondary-sewage sludge have been performed in Massachusetts. Sludge, as opposed to effluent, was chosen to facilitate application and includes toxins such as PCB's, pesticides, heavy metals and hydrocarbons trapped in the sludge (Teal and Valiela, 1973). According to Valiela et al. (1973), the retention of applied sewage sludge nutrients in the salt marshes can be substantial. Teal and Valiela (1973) applied up to $70 \text{ gN/m}^2/\text{year}$, of which approximately 15 g N were washed away by high tides soon after fertilizer application. (Using the effluent total nitrogen concentration of 25 mg/l from Table 6.1-2, 70 g N is contained in 2800 l of wastewater effluent). Nutrient losses were related to tidal exposure and amount of sludge application, with a greater application resulting in a greater percentage loss.

In addition to being removed from the salt marsh, nitrogen is also conserved and recycled within the saltwater-wetland ecosystem. Dissolved nitrogen forms (particularly ammonium and nitrates) are taken up by plants and bacteria and stored as biomass for varying periods of time. In general, application of nitrogenous nutrients can result in nitrogen uptake and increased plant biomass in nitrogen-limited systems but essen-

tially no growth change for non-nitrogen-limited systems. In saltmarsh areas where the supply of nitrogen is limited (e.g. higher marsh areas containing the short form of S. alterniflora), nitrogen could be removed from wastewater through incorporation into production of plant biomass. However, in areas where the availability of nitrogen is not a limiting factor in plant production (e.g. low marsh or creek bank areas containing tall S. alterniflora), or if the application of wastewater nitrogen exceeds the capacity of the plants to utilize it in biomass production, more wastewater nitrogen could potentially be washed out of the marsh and enter an estuary. Plant species vary in the amount of nitrogen they can assimilate, and nitrogen loading limits have been observed in some plants. For example, the peak above-ground biomass of Spartina alterniflora measured from the Great Sippewissett salt marsh leveled off after a sludge-fertilizer application of approximately 50gN/m²/year, while Distichlis spicata biomass values continued to rise with applications of over 200gN/m²/year (Valiela et al., unpublished). (Again using Table 6.1-2, 50 gN would be contained in 2000 l of wastewater, 200 g N in 8000 l of wastewater.) Annual peak above-ground biomass of S. alterniflora increased during the first four years of sludge fertilizer application but then decreased. Over a period of several years, D. spicata replaced S. alterniflora in high marsh areas of the test plot.

In addition to increasing plant productivity, the use of effluent fertilization may also extend the growing season. Hardisky et al. (1983) reports that the short form of S. alterniflora from a Delaware salt marsh irrigated with freshwater and primary-treated sewage effluent had its growing season extended by two months, with growth ceasing in October.

Wetland vegetation can absorb large amounts of nitrogen and phosphorus during the growing season, yet much of the stored nutrients can be released to the water when the plants die. When nitrogen is released by plants during decomposition of dead plant matter, it can either be recycled again, exported, or lost to sediment. Algae and bacteria also may temporarily store nitrogen unless it is trapped in sediments. Ammonia or nitrate-nitrogen may be taken up by plant roots for nutrition or may remain in organic matter until it is degraded or flushed out by tidal action. Figure 5.1-5, previously shown, depicts the nitrogen cycle.

Wastewater nitrogen applied to a wetland also can be removed from the wastewater by anaerobic bacterial denitrification in the soil. Denitrification requires a source of available organic carbon, which would be abundant in a salt marsh. However, the efficiency of nitrogen removal through denitrification decreases at higher loading rates (Nichols, 1983).

Because nitrogen is often the limiting nutrient for saltmarsh plants and nitrogen fixation is cut off when external nitrogen supplies are sufficient, salt marshes provide an environment that is potentially suitable for nitrogen enrichment by sewage and seafood-processing effluents. Such enrichment would enhance plant productivity and detrital formation as well as remove nitrogen from wastewater effluent. However, the wastewater nitrogen bound in plant biomass could potentially be transported from the saltwater wetland into an estuary, depending upon the rate of decomposition and frequency of tidal inundation.

Phosphorus

The phosphorus cycle is somewhat simpler than the nitrogen cycle. One significant difference between the two is that phosphorus cannot enter or leave a saltwater wetland in a gaseous form. The natural reservoir for phosphorus is rocks or other geological deposits. Inorganic or organic phosphorus normally enters saltwater wetlands from surface waters, groundwater, rain, or runoff depending on site-specific conditions.

Phosphorus is converted from its organic form to inorganic phosphorus in the sediments (Section 5.1.3.1) or in the wetland surface waters by hydrolysis. Figure 5.1-6, previously shown, presents the different pathways that exist for phosphorus. The pattern of phosphorus assimilation and release is dependent upon hydrologic conditions, vegetation, and sediment types of each wetland.

Wastewater phosphorus is readily retained in soils by adsorption and precipitation reactions with aluminum, iron, calcium and clay minerals (Nichols, 1983; see Section 5.1.3.1). Continued introduction of wastewater phosphorus to wetlands decreases the ability of wetland soils to retain phosphorus as the soils become saturated (Nichols, 1983). However, some phosphorus that is adsorbed from the water at high concentrations can be released to the water when phosphorus levels decrease. For example, when inorganic phosphate was applied to the surface of the Rhode River marsh in Massachusetts at a rate of 4.3 kg/ha/day (1 hectare = 2.47 acres) the binding capacity of the sediment was exceeded in 45

days (Bender, 1974). Test plots in the Great Sippewissett marsh fertilized with 600 kg/ha/year of a phosphate fertilizer showed a rapid buildup of dissolved phosphate in the sediment water to approximately 11 mg/l of phosphate phosphorus, with no indication of depletion over the winter when fertilizer application was halted. The system was overloaded and loading rates were reduced the following year, resulting in dissolved phosphate concentrations being decreased (Valiela, 1973). The removal of wastewater nitrogen and phosphorus by wetlands is most efficient at low loading rates. Citing studies of freshwater wetlands, Nichols (1983) reports that 1 hectare (2.47 acres) of wetland on the average is required to remove 50 percent of the nitrogen and phosphorus from the wastewater produced by 60 people. Higher removal rates require larger wetlands. The mechanisms for nutrient removal from wastewater in a saltwater wetland differ somewhat from those in a freshwater wetland, yet efficiency of removal would still be affected by loading rate.

Phosphorus is utilized by saltmarsh vegetation but it is apparently not a limiting factor in production of saltmarsh plants (Haines, 1979). Thus, in contrast with nitrogen, removal of wastewater phosphorus through plant production would not necessarily be enhanced by adding the effluent to areas containing a particular type of saltmarsh vegetation. Wastewater phosphorus utilized in plant production could eventually reenter water in the saltmarsh during decomposition of the vegetation.

5.4.2.2 Heavy Metals

Heavy metals and other toxins (pesticides, PCB's and hydrocarbons) that may be present in wastewater effluent must also be considered if saltwater wetlands are to be used as wastewater discharge systems. Toxic trace metals include copper, mercury, silver, chromium, cadmium, zinc and nickel (Engel et al., 1981), plus arsenic and lead. Conversely, some trace metals are micronutrients. These are iron, zinc, copper, manganese, cobalt and molybdenum (Engel et al., 1981). Copper and zinc are either trace metals or micronutrients depending on their concentration.

Heavy metals may enter a wetland ecosystem through several pathways of transport and translocation including movement of surface or groundwaters into the sediments, atmospheric fallout, and uptake by plants or animals. The form the metal takes in water is dependent on the individual metal, its concentration, and the chemical components and physical characteristics of the water, including its pH, salinity, presence of dissolved organics and conditions of oxidation or reduction (Engel et al., 1981). The chemical potential of a metal is an important variable in determining trace metal interactions with the biota present.

Examples of chemical forms of trace metals in natural waters include free ions, metals adsorbed on or incorporated into particulate matter, organic complexes and inorganic complexes (Engel et al., 1981). An example of an inorganic complex is a metal-sulfide complex, such as iron sulfide (FeS_2), which is insoluble and will precipitate. Metal chloride complexes, such as zinc chloride (ZnCl_2) and cadmium chloride (CdCl_2),

are soluble and present in saltwater (Giblin et al., 1980). In general, heavy-metal and chlorinated-hydrocarbon uptake by living organisms is increased by solubilizing conditions and is decreased by conditions associated with particulate phases (National Wetlands Technical Council, 1978). For example, the iron in water entering a salt marsh reacts with sulfides in the anaerobic sediment, thus forming insoluble iron sulfide (FeS_2). Diffusion of excess oxygen through the roots of S. alterniflora can oxidize iron sulfide and form insoluble iron oxide (rust) plus soluble ferrous sulfate, a form of iron that can be utilized by the plant (Teal and Teal, 1969).

Trace metal studies of copper, cadmium and silver demonstrate the complexity of aquatic chemistry and suggest that broad generalizations about metal chemistries and biological effects cannot be made (Engel et al., 1981). The free ion concentration of copper and cadmium, for example, appears to determine toxicity and bioaccumulation in marine organisms. As salinity increases, copper and cadmium ions form chloro-complexes, thus limiting their potential uptake by organisms. Silver also forms chloro-complexes as salinity increases; however, its accumulation by organisms at lower salinities is apparently related to both the free silver ion concentration and chloro-complexes. Thus the speciation of trace metals in water determines their toxicity and bioaccumulation in organisms exposed to water containing the metals.

The conclusions made by Engel et al. (1981) are supported by studies of the effects of metals added to salt marshes. For example, test plots

in the Great Sippewissett Marsh in Massachusetts were treated with fertilizer containing secondary-sewage sludge (including metals) over a seven-year period. Changes were exhibited in metal content for marsh sediments, grasses and animals (Giblin et al., 1980). Iron and lead were held in sediments in forms unavailable to marsh plants and animals (e.g. iron sulfide, FeS_2). Copper was similarly retained in sediment but was available to the biota. Chromium, cadmium and zinc were found to be highly mobile in treated plots and were utilized by the marsh plants and animals. In general, marsh sediments showed a retention of 20 to 35 percent for cadmium, 20 to 50 percent for chromium, 60 to 100 percent for copper, 55 to 100 percent for lead, 80 to 100 percent for iron, 55 to 60 percent for manganese and 20 to 45 percent for zinc added by the fertilizer. The high marsh area retained a considerably greater percentage of metals (except manganese) than the low marsh area, presumably because the low marsh was flooded by tides more often. Nixon (1982) also reported that lead, copper and iron were very tightly held by New England high salt marshes, while manganese, zinc and chromium showed only about 50 percent retention and cadmium somewhat less.

Removal of metals from wastewater added to a saltmarsh is thus a complex process. Although metals can be removed from the water and retained in the sediments, they can also be incorporated into plant and animal tissues. Animals feeding upon plants or detritus in the marsh accumulate these metals in their tissue and, in turn, pass these toxins up the food chain (bioaccumulation). The level of bioaccumulation varies with species and with the type of metal. (Section 5.5.6 discusses these

impacts to wildlife.) Metals accumulated in the tissues of marsh biota can potentially be reintroduced to the marsh water during decomposition of organic matter.

5.4.2.3 Pathogens

Secondary treatment of wastewater removes or destroys 90-98 percent of the bacteria present, while subsequent chlorination of this treated wastewater yields a 98-99 percent removal of bacteria (Metcalf and Eddy, Inc., 1979). However, chlorine is not as effective in inactivating enteroviruses (Weber, 1972). Most current disinfection techniques do not completely inactivate hepatitis and polio viruses.

Pathogens settled in sediments may be resuspended by physical disturbances such as dredging (Taylor, 1973). Ellender et al. (1980) reported that viruses can remain infectious in sediments and be returned to the water column through physical or chemical action. Fecal bacteria counts, however, are much reduced as compared to primary-sewage effluent, because of chlorination. If pathogenic bacteria or viruses are introduced to a saltmarsh through wastewater effluent and are subsequently carried out of the marsh through tidal action or stormwater drainage, they could potentially reach shellfish beds. Consumption of raw shellfish contaminated by sewage can result in the transmission of infectious hepatitis to humans (Kilgore and Li, 1980).

While chlorination of treated wastewater is of great importance in decreasing bacterial populations, chlorine itself could be detrimental to

the natural microbial population of a saltwater wetland. Dechlorination of treated wastewater prior to its addition to a saltmarsh would thus be highly desirable.

5.4.3 Assessment

Water quality of a saltwater wetland is dependent upon the complex physical and chemical reactions occurring within the wetland. The degree of change in water quality within a saltwater wetland receiving a wastewater addition would depend upon the physical and chemical characteristics of both the wastewater and the wetland, the fauna and flora associated with the wetland, and the location, method, volume, timing and frequency of wastewater application.

The path and rate of movement of wastewater through a saltwater wetland would affect changes in water quality within the wetland. Application of wastewater in high marsh, rather than low marsh, areas would allow greater interaction of wastewater and the wetland, thus allowing more wastewater components to be retained within the wetland rather than being carried out relatively unchanged into an estuary.

The fate of components of wastewater, such as nutrients and metals, would depend not only upon their concentration in the water but also upon their chemical form or speciation and conditions in the wetland at the site and time of application. In addition, a chemical component would not necessarily remain in one compartment of the wetland. Changes in physical or chemical conditions could cause a nutrient, for example, to

be in solution in wetland water, bound in sediments, or utilized in plant or animal production.

Many physical and chemical reactions which occur within a saltwater wetland have limitations. The limitations of nitrogen utilization by Spartina and the adsorption of phosphorus by clay sediment particles have already been discussed. Thus, once the dynamic processes related to water quality have been defined, it is important to determine the rates of the reactions and their limiting factors.

Interactions of water (both saline and fresh) with air, soil and biota cause changes in water quality over time. However, these changes can be cyclic, occurring on a diel, twice-monthly (related to tides), monthly (lunar), seasonal or annual basis. The wastewater-effluent and sludge-fertilizer studies cited earlier in this section were based upon weekly or twice-monthly applications. In determining loading limits for components of wastewater added to a saltwater wetland, one must consider not only the volume of the addition but also the frequency of application. A wetland might be more capable of handling a chemical component applied at low concentrations over longer periods of time rather than the same total concentration added during fewer applications. On the other hand, a periodic, rather than constant, application would mimic the natural tidal cycle of inundation within the wetland. Many saltmarsh plants and animals have adapted to these tidal cycles; for example, S. alterniflora can survive temporary, but not constant, flooding of the marsh (Teal and Teal, 1969). Seasonal changes within a saltwater wetland

can affect its response to wastewater additions. For example, short S. alterniflora can remove inorganic nitrogen from wastewater only during its growing season. During the winter months, wastewater nitrogen could be removed through algal production or bacterial denitrification, but the rate of removal might differ. In addition, possible seasonal changes in the water quality and/or volume of wastewater itself must be taken into account.

Application of wastewater to a saltwater wetland can result in both immediate and delayed changes in water quality. For example, phosphorus in wastewater is rapidly adsorbed onto clay particles in the sediment and later resuspended during times of low phosphorus concentration of wetland water. Although concentrations of toxic heavy metals or pathogens might be very low in secondary treated wastewater, they could accumulate in wetland sediments or in the biota, with the potential for later resuspension in water.

The addition of nutrient-rich wastewater might cause increased primary productivity within a wetland. However, increased productivity eventually leads to an increase in dead vegetation. Depending upon the decomposition rate and degree of flushing in that area of the wetland, nutrients released during decomposition could remain in the wetland sediment or could reenter the wetland water and possibly be carried out to an estuary. If the nutrients remain in the wetland area, the ability of the wetland flora to use the nutrients in subsequent wastewater additions might be decreased. Thus, if wastewater additions bring about changes in

the structure of the wetland (including the floral community) over time, then changes in water quality during subsequent wastewater additions might differ from those which occurred during the initial wastewater additions.

Three other factors might affect water quality within a saltwater wetland. Wetlands located near developed areas might already be under stress from pollution and siltation. Secondly, the wastewater application system would need provisions for handling of wastewater under unusual conditions, such as treatment-system breakdown (including chlorination failure) or extreme weather conditions. Otherwise high concentrations of pathogens or toxic chemicals could enter the wetland and possibly be carried out to an estuary. One last aspect to consider is the potential impact on a wetland which has adjusted to regular wastewater application if wastewater additions are subsequently discontinued.

In summary, the basic water quality changes in a saltwater wetland receiving secondary-treated wastewater or seafood-processing effluent would probably be as follows:

1. Dissolved oxygen and salinity would decrease.
2. Turbidity would increase.
3. Potential changes in the pH of surface water might be counteracted by buffering within the wetland.
4. Nutrients could potentially be removed from wastewater through utilization in plant production or binding in sediments; however, nutrients could reenter the water during decomposition of dead vegetation or resuspension from sediments.

5. Heavy metals could be bound in sediments or incorporated in plant production; however, the metals might later be resuspended in the water or they could pass through food chains.
6. Pathogenic viruses or bacteria which settle in sediments might remain viable and might also later be resuspended in water.

Further information is needed on the natural physical and chemical processes occurring within the different types of saltwater wetlands in the Southeastern Region. In addition, the content of particular effluents should be identified. More pilot studies would be needed to determine the effects of secondary-treated wastewater or seafood-processing effluents on various types of wetlands and different areas within each wetland. Since environmental conditions are not exactly alike for all saltwater wetlands, both baseline and operational environmental monitoring would be needed for each wetland under consideration for wastewater application.

5.5 WILDLIFE

The estuarine zone, including the salt marsh, forms a vast ecosystem that provides food, cover and nesting area for an abundance of wildlife (Sandifer, 1980; Gusey, 1981; O'Neill and Mettee, 1982). The wildlife species associated with coastal salt marshes are supported by a highly-productive habitat that is the result of three separate, but interdependent, units of primary production. These units are marshes and their resultant detritus, benthic organisms, and plankton (Schelske and Odum, 1962; Sandifer et al., 1980; Gusey, 1981).

The flow of energy through the marsh community starts with the fixation of sunlight by plants. This primary production is the basic form of energy storage in the ecosystem. The energy stored by plants is passed along through the ecosystem in a series of steps known as a food chain. At each step in the food chain, a considerable portion of the potential energy is used for maintenance or lost as heat. As a result, organisms at each trophic (feeding) level pass on less energy than they receive.

Detritus from decomposing salt marsh plants forms the primary basis of the food chain in south Atlantic and Gulf coast marshes (Shelske and Odum, 1962; Teal, 1962). Benthic and planktonic algae also contribute to the basis of marsh food chains and initiate a massive conversion of energy (Gusey, 1981). Figure 5.5-1 depicts the flow of energy in a representative estuarine ecosystem. This energy, in the form of mineral and organic nutrients, is distributed to all niches within an estuarine habitat by tidal and wind action, circulation and marsh flushing. Shallow water and reduced tidal and wave action contribute to the retention of particulate matter. These conditions provide suitable habitat for a variety of organisms.

Bottom-feeding, filter-feeding and burrowing animals directly utilize detritus. Conspicuous algae-detritus feeders are fiddler crabs (Uca and Sesarma spp.), horse mussels (Modiolus demissus) and the saltmarsh periwinkle (Littorina irrorata), in addition to a variety of annelid worms, oligochaetes and insect larvae (Odum, 1974). Burrowing animals also feed on smaller animals, bacteria and minute plants. Intertidal

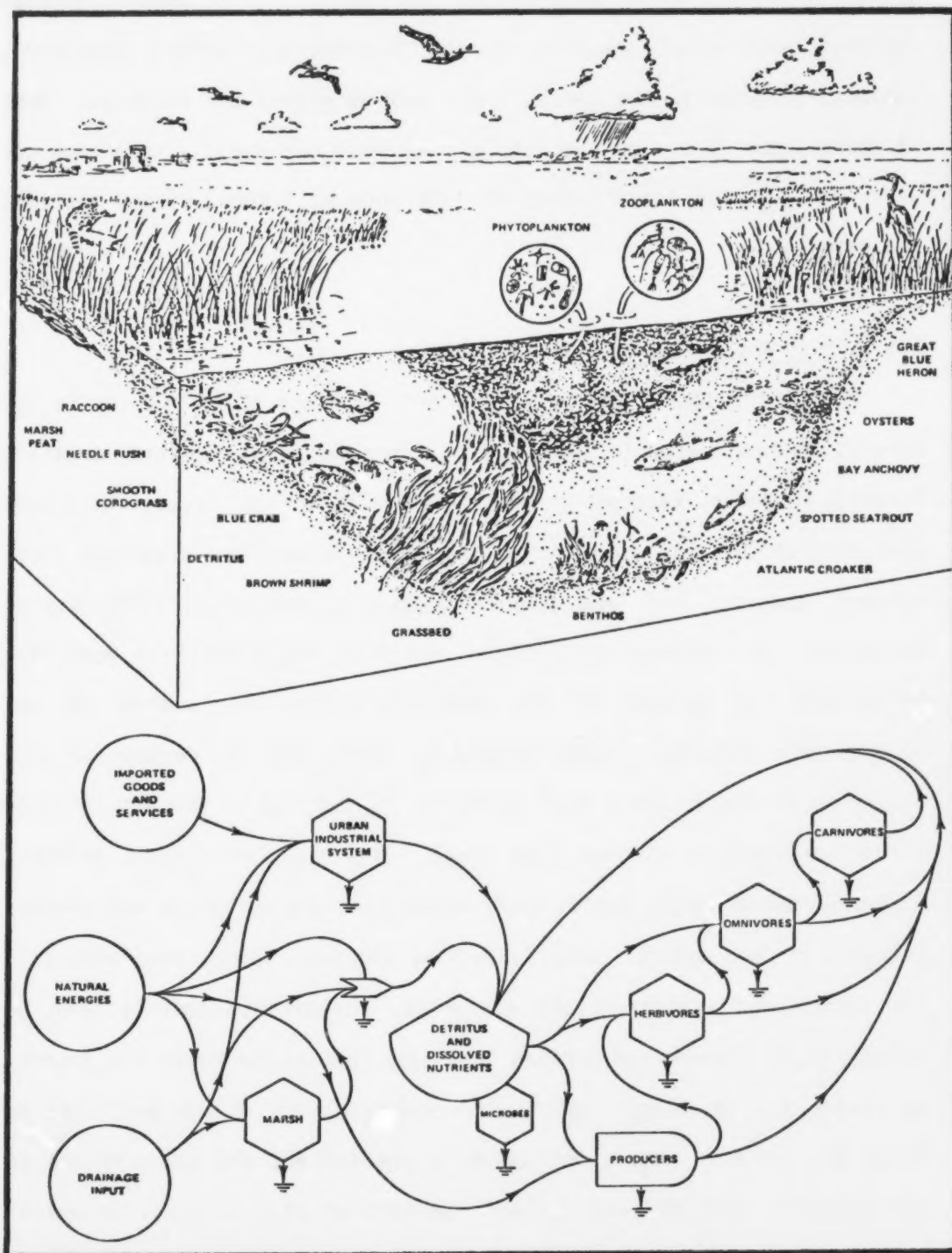


Figure 5.5-1. The estuarine ecosystem of coastal Alabama and representative energy symbols. (O'Neil and Metke, 1982)

oyster clusters provide microhabitats and food for other benthic species including mud crabs, snapping shrimp, juvenile blue crabs, amphipods, isopods, polychaetes and small fishes such as gobies and blennies. Most of these lower levels of the food web exchange and recycle nutrients and serve as food for larger forms of life such as fishes, birds, reptiles and mammals.

5.5.1 Fish and Shellfish

One of the most frequently reported functions of an estuary is its role as a nursery area for many marine organisms (e.g., Atlantic croaker, Atlantic menhaden, seatrout or drum, blue crab, shrimp, etc.). Many species of fish that live or spawn at sea as adults utilize estuaries, tidal marshes, seagrass beds and mangrove swamps as postlarval forms and as juveniles. The species of fish and shellfish responsible for more than 85 percent (by weight) of the commercial fisheries landings of the southeastern Atlantic states (Burrell, 1975) and 98 percent of the fisheries in the northern Gulf of Mexico (Gunter, 1961) are estuarine or estuarine-dependent at some life stage. One group of migrant Atlantic fishes (croaker, spot) spends their summers in the estuaries and winters offshore in deep waters. Others, such as flounder, prefer deep waters in the summer and winter in the estuaries. Anadromous species such as salmon, shad, alewife and striped bass pass through estuaries and journey up rivers for spawning. Catadromous species, such as the eel, live in fresh and brackish waters but spawn in the sea and the young return to the estuaries and to fresh waters (Walford et al., 1972). Estuarine-dependent species comprise a majority of the recreationally and commer-

cially important fisheries of the Gulf and south Atlantic (Beccasio et al. 1980, 1982).

The most abundant fish and those with the highest annual biomass in intertidal estuarine wetlands are those that feed on decayed plant and animal tissue (detritivores) or on plants (primary consumers). Since feeding behavior often changes as these fish grow, they are not limited to one trophic level (Sandifer et al., 1980). For the many species that spawn in estuaries or use them as nursery grounds, an abundant plankton population is necessary to provide food for larval and postlarval fish and other forms (Sandifer et al., 1980). Common food relationships are illustrated in Figure 5.5-2. Plankton biomass and populations are usually greater in estuaries than in other aquatic habitats (Sandifer et al., 1980). The proximity of estuarine waters to marsh land increases the environmental variables by exposing phytoplankton populations to urban, industrial and agricultural discharges, as well as to the normal constituents of marsh drainage.

5.5.2 Birds

The most conspicuous form of wildlife in a salt marsh is the bird population. Salt marsh vegetation serves as a base for feeding, resting, reproduction and roosting activities for many breeding and non-breeding birds. The large avian population consists of shorebirds, wading birds, waterfowl, raptors, sea birds, songbirds and others. Feeding habitats provided by marshlands vary with tides, seasons, plant species and vegetation height and abundance. The nesting activities of many marsh birds,

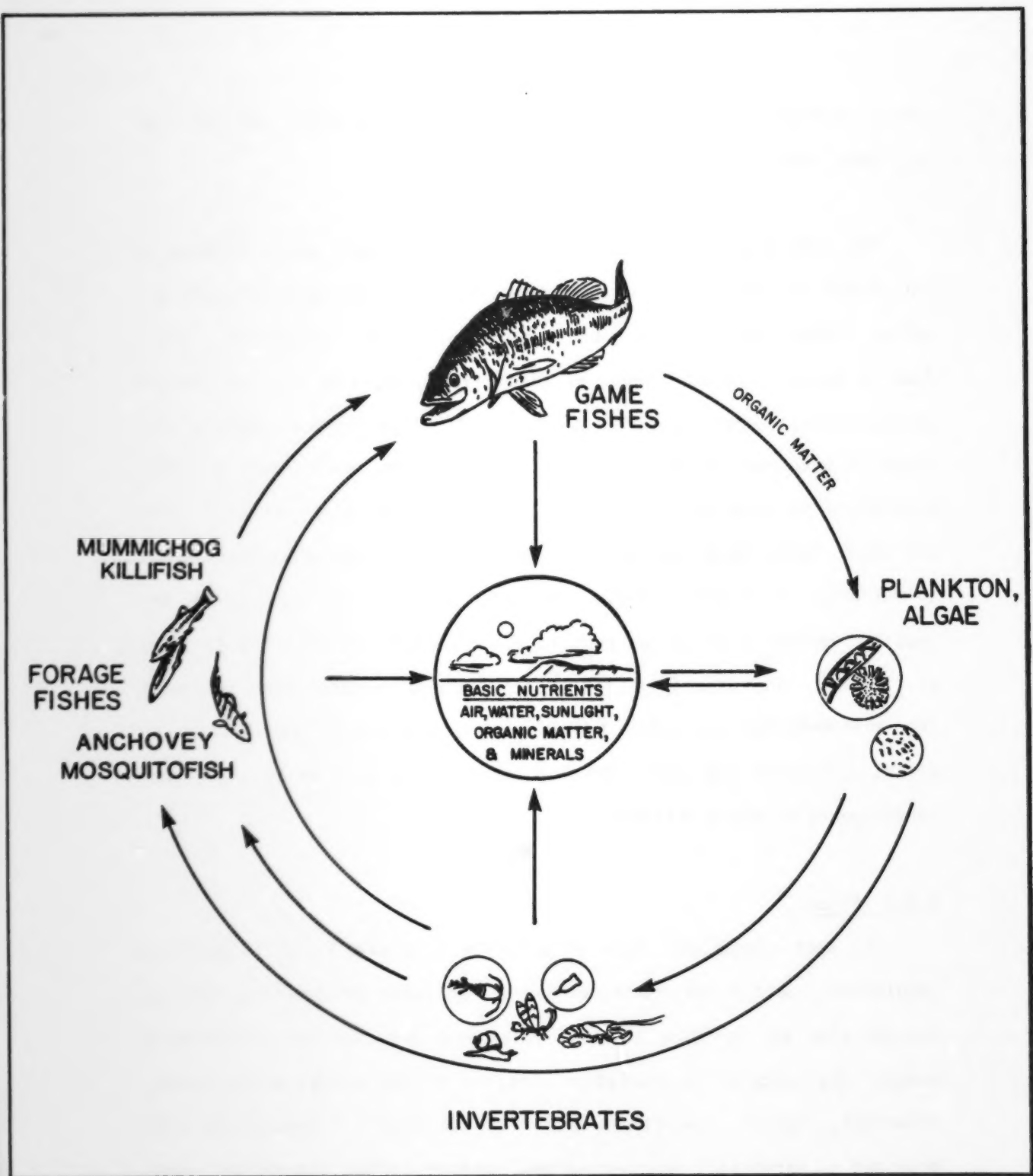


Figure 5.5-2. Common Food Relationships.

for example, the marsh wren, often occur in conjunction with feeding activities (Sandifer et al., 1980). Other marsh birds (herons, for example) nest in colonies away from feeding territories. Salt marshes are also used for surface-roosting species such as the rails, while red-winged blackbirds, swallows and wrens are plant-roosting species.

Ecologically, the dominant bird species can be grouped according to their different trophic levels such as birds of prey, fish eaters, scavengers, insect feeders, aquatic plant eaters, those that feed on benthos, and omnivores (feed on plants and animals) as illustrated in Figure 5.5-3. Several species of hawks and owls, among other birds of prey, make use of salt marshes as hunting areas. These birds of prey feed on other birds such as clapper rails and, to a greater extent, small mammals including marsh rabbits and rodents. Eagles and ospreys are heavily dependent on the fish populations of the salt marsh. Approximately 70 percent of bald eagles nest in marsh or estuarine habitats (Sandifer et al., 1980). Herons and egrets, ibises, spoonbills, terns and other species found in Atlantic and Gulf coast salt marshes are predators of fish, shrimp and fiddler crabs.

There is considerable overlap in birds using estuarine and marine habitats. For example, various shorebirds will use wracks of dead smooth cordgrass as nesting sites. During long migration seasons, many species of shorebirds such as plovers and various sandpipers, the long-billed yellowlegs, oyster catchers and dowitchers will occupy estuarine marshes (Sandifer et al., 1980). These species consume mostly smaller crusta-

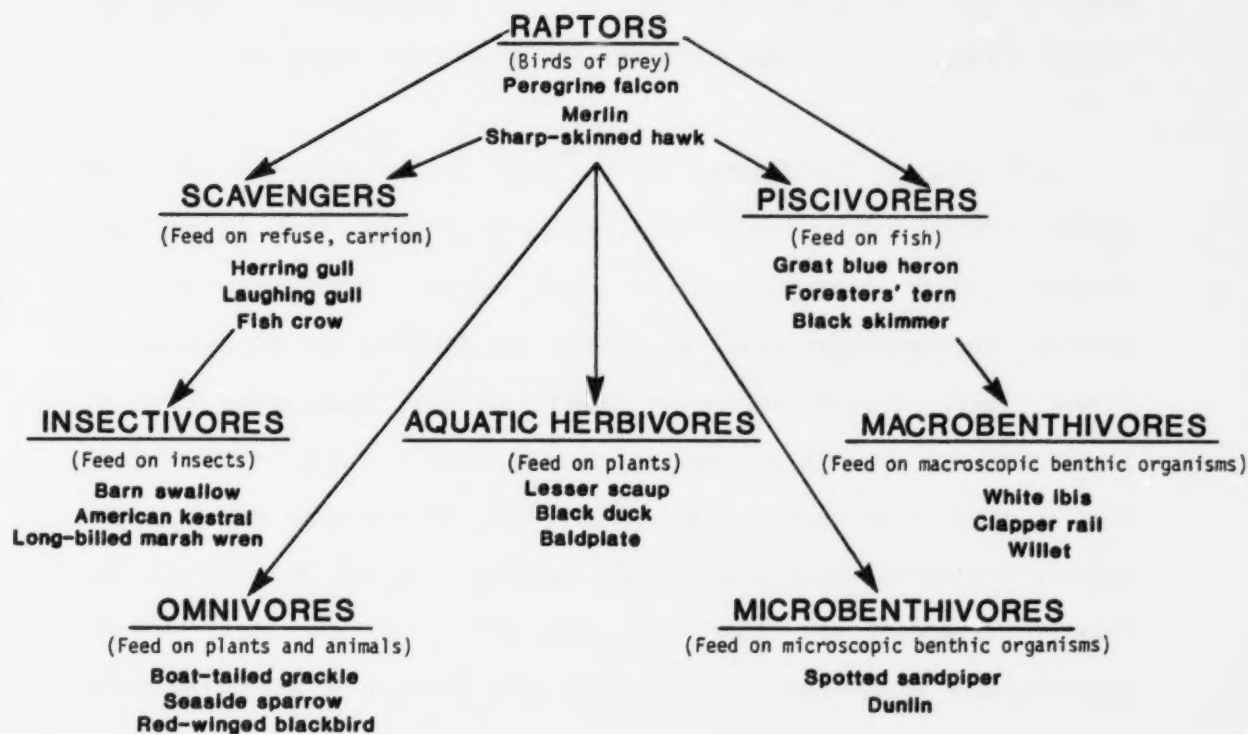


Figure 5.5-3. Generalized trophic relationships of representative birds of estuarine emergent wetlands. (Sandifer et al., 1980)

ceans, mollusks and annelids. Fish-eating species such as pelicans and cormorants also use the estuarine habitats intensively.

Scavengers, such as gulls and fish crows, utilize estuarine shores and waters during portions of the year. Major nesting groups of gulls and terns are found along both the Atlantic and Gulf coasts, feeding offshore and in estuaries and breeding on the beaches and islands.

Birds very often represent end-points in the consumer food chains of salt marshes (Gusey, 1981). This is often the case with insectivores. Insects serve as an important food source in the wetland community. They depend on detritus, algae and saltmarsh vegetation and, in turn, are preyed upon by various species of birds including marsh wrens, swallows, kestrels, warblers, blackbirds and sparrows. Species from all major insect orders have been recorded from salt marshes. Approximately 75 percent of those salt marsh species recorded consist of Diptera (flies, mosquitos and midges), Coleoptera (beetles) and Hemiptera (true bugs).

The most important birds of sporting interest in estuaries are the waterfowl such as ducks and geese. Nearly every American waterfowl species inhabits estuarine areas at some point in its life (Sandifer et al., 1980). For some, such as brant, the estuaries provide all their needs. For others, salt marshes provide resting grounds, food and refuge during migration and wintering (redhead, gadwall, teals, black duck, canvasback, wigeon, etc.). Submerged aquatic vegetation provides most of the food for these species. The only reported waterfowl whose entire nesting

range lies along the south Atlantic and Gulf coast is the Florida duck (Gusey, 1981).

5.5.3 Reptiles and Amphibians

Most amphibians and reptiles are associated with freshwater, marine or terrestrial habitats, although some are infrequently encountered in saltwater wetlands (Beccasio et al., 1980, 1982; Sandifer et al., 1980; O'Neil and Mettee, 1982). Most records are of individuals reported from particular locations but, because of the similarity of saltwater-wetland habitats along the south Atlantic coast and the Gulf coast, the species mentioned below would be expected to occasionally visit or utilize other saltwater-wetland habitats given similar conditions.

The amphibian population is comparatively small in a salt marsh. Some of the more commonly reported species include: southern toads, observed in irregularly flooded areas (for example Shackelford Banks, NC), and eastern narrowmouth toads reported in glasswort flats in Florida (Engels, 1952; and Neil, 1958, respectively). Other frogs associated with saltmarsh vegetation include grass frogs, green tree frogs, chorus frogs, squirrel tree frogs and southern leopard frogs.

Snakes have occasionally been sighted in saltwater wetlands and include the banded water snake, eastern mud snake, cottonmouth, yellow rat snake, rough green snake, saltmarsh water snake and brown water snake (Sandifer et al., 1980; O'Neil and Metter, 1982). Eastern garter snakes and island glass lizards were also found in association with fiddler crab burrows.

Estuarine waters are also frequented by marine species of turtles. The Atlantic loggerhead, Atlantic leatherback and Atlantic green turtles, for example, are reported to ascend tidal creeks to the freshwater zone and above (O'Neil and Mettee, 1982). Diamondback terrapin occur in coastal rivers, creeks and estuaries of the coastal salt marsh, particularly over shell bottoms and near oyster bars. Preferred food items include snails, fiddler crabs, annelid worms and smooth cord grass (Sandifer et al., 1980). Other species associated with coastal salt marshes include the striped mud turtle and the eastern mud turtle. The snapping turtle and chicken turtle are commonly hunted for food in the Alabama coastal area (O'Neil and Mettee, 1982).

Alligators will enter brackish water and coastal marshes (Parker and Dixon, 1980). Their diet varies and includes reptiles, mammals, amphibians, birds and fishes. The American alligator occurs from North Carolina southward around the coastline to Corpus Christi, Texas, encompassing the study region. The American crocodile occurs in salt or brackish waters of extreme southern Florida.

5.5.4 Mammals

Many mammals thrive in estuarine areas including small rodents, furbearers and large animals such as deer. Aquatic species such as manatees and porpoise also live within the study region.

The marsh rabbit constitutes an important link in the food chain to birds of prey. It has been reported that the marsh hawk in salt marshes

of South Carolina and Georgia depends primarily on marsh rabbits during winter (Sandifer et al., 1980). Other objects of prey include the marsh rice rat and the cotton rat (Sharp, 1962; O'Neil and Mettee, 1982). The marsh rice rat is among the most highly aquatic of the coastal rodents and is an important predator and prey, feeding on fiddler crabs, insects and wren's eggs. The coastal race of the swamp rabbit is restricted to a narrow belt along the Gulf coast of Alabama (O'Neil and Mettee, 1982).

Furbearers are relatively abundant in salt marshes and include the river otter, muskrat, raccoon, mink and nutria, which are a basis for valuable fur industries in some states. Weasels, opossum, foxes and bobcats are also occasionally taken in the marshes by trappers (Sandifer et al., 1980; Gusey, 1981). The diet of furbearers is comprised of fish and crustaceans, and sometimes insects, birds, rodents, oysters and clams. The young of these mammals may be taken by birds of prey; as adults, natural mortality may occasionally be caused by alligators or bobcats.

Larger mammals include white-tailed deer, which often graze in the high marsh, feeding on saltmeadow cordgrass or glasswort. The manatee spends its entire life in water. In winter the manatee lives in the southern half of the Florida peninsula and, in summer, it moves north and west along the Atlantic and Gulf coasts to North Carolina and extreme western Florida (Parker and Dixon, 1980). Individuals have also been observed on the northern Gulf coast from Pensacola to New Orleans (O'Neil and Mettee, 1982).

5.5.5 Threatened and Endangered Wildlife Species

Saltwater wetlands harbor a wide diversity of fish and wildlife, many of which are dependent on this habitat type for survival. Adequate tracts of these wetland areas are therefore needed if many species are to remain in existence. The density and diversity of species present in saltwater wetlands depends on the needs of the species, the ecological status of the wetland, the population status of the species where the wetland is located, climate and other factors. The causes of population increases or declines for coastal species are highly variable; however, the key element in the decline of many species is the growth of the human population into coastal areas. The spread of environmental contaminants along with alteration of land-use patterns associated with development may contribute to the extirpation of certain species and/or their habitat.

Passage of the Endangered Species Act of 1973 provided the protection needed for several species of wildlife to survive. The Act created a national program that currently involves federal and state governments, conservation organizations, individual citizens, business and industry, and foreign governments in a cooperative effort to conserve endangered wildlife.

5.5.5.1 Federal Involvement

The Federal Endangered Species Act of 1973 was amended in 1978 to direct the Secretary of the Interior and the Secretary of Commerce to develop plans for the survival and conservation of federally-listed

endangered or threatened species. The Secretary of the Interior, acting through the U.S. Fish and Wildlife Service has broad authority to protect and conserve all forms of flora and fauna considered to be in jeopardy, and the Secretary of Commerce, acting through the National Marine Fisheries Service, has similar power to protect and conserve most marine life.

An "endangered" species, by definition, is one on the brink of extinction throughout all or a significant portion of its range. A "threatened" species is one likely to become endangered within the foreseeable future. Restoring these listed creatures to the point where they are viable and self-sustaining members of their ecosystems is the main goal of the Fish and Wildlife Service's Endangered Species Program. The Endangered Species Act also emphasizes the need to preserve critical habitats on which endangered species depend for their continued existence. Critical habitats are those areas of land, water and air space that an endangered or threatened species needs for survival. These areas include breeding sites, cover and shelter, and surrounding habitat that provide for normal population growth and behavior. In USEPA Region IV, critical habitats have been established for several species associated with saltwater wetlands. Critical habitat designations affect strictly federally authorized activities and are made mainly to assist federal agencies in locating endangered species and in fulfilling their conservation responsibilities under the Endangered Species Act. Critical habitats have been established to protect species including the manatee, dusky seaside sparrow, and Cape Sable seaside sparrow in Florida. Tables

5.5-1 through 5.5-6 present endangered and threatened species listed by the USFWS by state.

Endangered and potentially endangered species are protected by additional federal laws including the Migratory Bird Treaty Act, Migratory Bird Conservation Act, Land and Water Conservation Fund Act, National Environmental Policy Act, Marine Mammal Protection Act and Fish and Wildlife Conservation Act. Many states also play a role in conserving endangered and threatened species. Certain states have entered into cooperative agreements with the USFWS, making the states eligible to receive federal financial assistance to improve their conservation programs.

5.5.5.2 State Involvement

Each state in USEPA Region IV maintains a list of endangered or threatened species. Included in these lists are species that are associated with saltwater wetlands. For the purpose of this report, salt water-wetland species classified as threatened, of special concern, or endangered, are species that depend on saltwater wetland habitat for food, water, shelter and/or reproductive needs during at least some portion of their life cycle. Tables 5.5-1 through 5.5-6 present individual state lists for saltwater wetland species.

State-listed species of endangered or threatened status may or may not be protected by state laws or statutes. Certain states lack an ultimate authority with the enforcement capabilities necessary to protect

endangered species. The environmental resource agency responsible for maintaining and updating a state list of species of concern is given by state for USEPA Region IV in the sections that follow. Most state lists include those species on the federal list in addition to endemic wildlife considered endangered, threatened or of special concern by the appropriate state officials.

North Carolina

The State of North Carolina has not adopted specific statutory authority for the protection of endangered species. However, North Carolina's Wildlife Resources Commission (WRC) has a cooperative agreement with the U.S. Fish and Wildlife Service for the establishment of an endangered species program for animals, and the WRC is responsible for monitoring the effects of proposed projects on these species. The terms "threatened" and "endangered", as defined by the Endangered Species Act of 1973, are used to classify the status of North Carolina's species of concern. The State list of endangered and threatened species is currently the same as the Federal list (Table 5.5-1).

South Carolina

The South Carolina General Assembly passed the South Carolina Nongame and Endangered Species Conservation Act in 1976. This Act required the South Carolina Wildlife and Marine Resources Commission to develop a list of those species of nongame wildlife endangered within the state and to conduct programs for the management of nongame or endangered species. Under this act, 25 species are afforded protection, those that are associated with saltwater wetlands are included in Table 5.5-2.

TABLE 5.5-1
NORTH CAROLINA'S PROTECTED SPECIES ASSOCIATED WITH SALTWATER WETLANDS

Scientific name	Common name	Status	
		State	Federal
MAMMALS			
<u>Trichechus manatus</u>	Manatee		Endangered
<u>Felis concolor cougar</u>	Eastern cougar		Endangered
<u>Felis concolor coryi</u>	Florida panther		Endangered
BIRDS			
<u>Haliaeetus leucocephalus</u>	Bald eagle		Endangered
<u>Pelecanus occidentalis carolinensis</u>	Brown pelican		Endangered
<u>Dendroica kirtlandii</u>	Kirtland's warbler		Endangered
<u>Falco peregrinus tundrius</u>	Arctic peregrine falcon		Endangered
REPTILES AND AMPHIBIANS			
<u>Dermochelys coriacea</u>	Atlantic leatherback turtle		Endangered
<u>Alligator mississippiensis</u>	American alligator		Endangered
<u>Chelonia mydas</u>	Green turtle		Threatened
<u>Eretmochelys imbricata</u>	Hawksbill turtle		Endangered
<u>Lepidochelys kempii</u>	Kemp's (Atlantic) ridley turtle		Endangered
<u>Caretta caretta</u>	Loggerhead turtle		Threatened
FISH			
<u>Acipenser brevirostrum</u>	Shortnose sturgeon		Endangered

Adapted from: Parker and Dixon, 1980; USFWS, 1982b.

TABLE 5.5-2

SOUTH CAROLINA'S PROTECTED SPECIES ASSOCIATED WITH SALTWATER WETLANDS

Scientific name	Common name	Status	
		State	Federal
MAMMALS			
<u>Trichechus manatus</u>	Manatee		Endangered
<u>Felis concolor cougar</u>	Eastern cougar		Endangered
<u>Felis concolor coryi</u>	Florida panther		Endangered
BIRDS			
<u>Dendroica kirtlandii</u>	Kirtland's warbler		Endangered
<u>Vermivora bachmanii</u>	Bachman's warbler		Endangered
<u>Falco peregrinus tundrius</u>	Arctic peregrine falcon		Endangered
<u>Pelecanus occidentalis</u>	Brown pelican		Endangered
<u>Haliaeetus leucocephalus</u>	Bald eagle		Endangered
<u>Aquila chrysaetos</u>	Golden eagle	Endangered	
<u>Passerculus sandwichensis princeps</u>	Ipswich sparrow	Endangered	
<u>Mycteria americana</u>	Wood stork	Threatened	
<u>Pandion haliaetus</u>	American osprey	Threatened	
<u>Sterna albifrons</u>	Least tern	Threatened	
<u>Numenius borealis</u>	Eskimo curlew	Threatened	Endangered
REPTILES AND AMPHIBIANS			
<u>Alligator mississippiensis</u>	American alligator		Threatened
<u>Caretta caretta</u>	Loggerhead turtle		Threatened
<u>Chelonia mydas</u>	Green turtle		Threatened
<u>Lepidochelys kempii</u>	Kemp's (Atlantic) ridley turtle		Endangered
<u>Eretmochelys imbricata</u>	Hawksbill turtle		Endangered
<u>Dermochelys coriacea</u>	Leatherback turtle		Endangered
FISH			
<u>Acipenser brevirostrum</u>	Shortnose sturgeon		Endangered

Adapted from: South Carolina Wildlife and Marine Resources Department Species List; USFWS, 1982b; Parker and Dixon, 1980.

The South Carolina endangered species program is coordinated with the Heritage Trust Program, which allows donations of land or easements that constitute endangered species habitat. Authority to protect wildlife and their habitat is granted through several other acts of legislation including the South Carolina Coastal Zone Management Act of 1977, Marine Fisheries Laws (1976), Shellfishing Laws (1976) and the South Carolina Pollution Control Act.

Georgia

Georgia's State legislature passed an Endangered Wildlife Act in 1973 to protect endangered species. This Act required the Georgia Department of Natural Resources (DNR) to identify species considered endangered, threatened, rare or unusual. The first lists of protected species were approved by the Georgia Board of Natural Resources in 1975 and have since been revised (Odom et al., 1977). The classes of protection are defined as follows:

Endangered species - any resident species which is in danger of extinction throughout all or a significant portion of its range, or one which is designated as endangered under the provisions of the Federal Endangered Species Act of 1973 (P.L. 93-205).

Threatened species - any resident species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range or one that is designated as threatened under the provisions of the Federal Endangered Species Act of 1973 (P.L. 93-205).

Rare species - any resident species which, although not presently endangered or threatened as previously defined, should be protected because of its scarcity.

Unusual species - any resident species which exhibits special or unique features and because of these features deserves consideration in its continued survival in the State.

The DNR has compiled a list of 23 protected species of wildlife that may depend on saltwater wetlands at some point in their life cycle (Table 5.5-3). The Endangered Wildlife Act provides that only habitats on public lands shall be protected (Smith, 1978). Wetland habitat protection is also afforded by means of the Coastal Marshlands Protection Act of 1970 and the State Water Quality Control Act which specifically provides for the consideration of the impact of discharged waters on fish and wildlife.

Florida

Florida enacted the Florida Endangered and Threatened Species Act of 1977 to provide for research and management in order to conserve and protect endangered and threatened species as a natural resource. The Game and Fresh Water Fish Commission (GFWFC) is responsible for research and management of freshwater and upland species and the Department of Natural Resources (DNR) is responsible for marine species. Florida has more endangered and threatened species than any other continental state, and it is the GFWFC's responsibility to maintain the State Endangered Species List. Of the 99 species of wildlife listed, 46 species are associated with saltwater wetlands at some point in their life cycles (Table 5.5-4).

Florida's protected species are defined as follows:

Endangered - any species of fish and wildlife naturally occurring in Florida whose prospects of survival is in jeopardy due to modification or loss of habitat, over-utilization for commercial, sporting, scientific or educational purposes, disease, predation, inadequacy of regulatory mechanisms, or other natural or man-made factors affecting its continued existence.

TABLE 5.5-3

GEORGIA'S PROTECTED SPECIES ASSOCIATED WITH SALTWATER WETLANDS

Scientific name	Common name	Status	
		State	Federal
MAMMALS			
<u>Trichechus manatus latirostris</u>	Manatee		
<u>Felis concolor coryi</u>	Florida panther	Endangered	Endangered
BIRDS			
<u>Falco peregrinus tundrius</u>	Peregrine falcon	Endangered	Endangered
<u>Falco peregrinus anatum</u>	American peregrine falcon	Endangered	Endangered
<u>Haliaeetus leucocephalus</u>	Southern bald eagle	Endangered	Endangered
<u>Pelecanus occidentalis carolinensis</u>	Brown pelican	Endangered	Endangered
REPTILES AND AMPHIBIANS			
<u>Alligator mississippiensis</u>	American alligator	Endangered	Threatened
<u>Dermochelys coriacea</u>	Atlantic leatherback turtle	Endangered	Endangered
<u>Eretmochelys imbricata</u>	Atlantic hawksbill turtle	Endangered	Endangered
<u>Lepidochelys kempii</u>	Kemp's (Atlantic) ridley turtle	Endangered	Endangered
<u>Chelonia mydas</u>	Green trutle		Threatened
<u>Caretta caretta</u>	Loggerhead turtle		Threatened
FISH			
<u>Acipenser brevirostrum</u>	Shortnose sturgeon	Endangered	Endangered

Adapted from: Odom, et al., 1977; USFWS, 1982b.

TABLE 5.5-4

FLORIDA'S PROTECTED SPECIES ASSOCIATED WITH SALTWATER WETLANDS

Scientific name	Common name	State	Status
MAMMALS			
<u>Sciurus niger avicennia</u>	Mangrove fox squirrel	Threatened	
<u>Oryzomys argentatus</u>	Silver rice rat	Endangered	
<u>Peromyscus gossypinus allapaticola</u>	Key Largo cotton mouse	Endangered	
<u>Procyon lotor auspicatus</u>	Key Vaca raccoon	Threatened	
<u>Mustela vison evergladensis</u>	Everglades mink	Threatened	
<u>Felis concolor coryi</u>	Florida panther	Endangered	Endangered
<u>Trichechus manatus latirostris</u>	Caribbean manatee	Endangered	Endangered/ Critical Habitat
<u>Odocoileus virginianus clavium</u>	Key deer	Threatened	Endangered
BIRDS			
<u>Pelicanus occidentalis carolinensis</u>	Eastern brown pelican	Threatened	Endangered
<u>Mycteria americana</u>	Wood stork	Endangered	
<u>Haliaeetus leucocephalus</u>	Bald eagle	Threatened	Endangered
<u>Falco sparverius paulus</u>	Southeastern kestrel	Threatened	
<u>Falco peregrinus</u>	Peregrine falcon	Endangered	Endangered
<u>Charadrius alexandrinus tenuirostris</u>	Southeastern snowy plover	Endangered	
<u>Grus canadensis pratensis</u>	Florida sandhill crane	Threatened	
<u>Haematopus palliatus</u>	American oystercatcher	Special Concern	Special Concern
<u>Florida caerulea</u>	Little blue heron	Special Concern	Special Concern
<u>Egretta thula</u>	Snowy egret	Special Concern	Special Concern
<u>Dichromanassa refescens</u>	Reddish egret	Special Concern	Special Concern
<u>Hydranassa tricolor</u>	Louisiana heron	Special Concern	Special Concern
<u>Ajaia ajaja</u>	Roseate spoonbill	Special Concern	Special Concern
<u>Aramus guarauna</u>	Limkin	Special Concern	Special Concern
<u>Sterna dougallii</u>	Roseate tern	Threatened	Threatened
<u>Sterna albifrons</u>	Least tern	Threatened	Threatened
<u>Cistothorus palustris marianae</u>	Marian's marshwren	Special Concern	Special Concern
<u>Cistothorus palustris griseus</u>	Worthington's marshwren	Special Concern	Special Concern

TABLE 5.5-4
(continued)

FLORIDA'S PROTECTED SPECIES ASSOCIATED WITH SALTWATER WETLANDS

Scientific name	Common name	Status	
		State	Federal
BIRDS (cont'd)			
<u>Amnospiza maritima nigriscens</u>	Dusky seaside sparrow	Endangered	Endangered/ Critical Habitat
<u>Amnospiza maritima mirabilis</u>	Cape Sable seaside sparrow	Endangered	Endangered/ Critical Habitat
<u>Amnospiza maritima peninsulae</u>	Scott's seaside sparrow	Special Concern	Special Concern
<u>Amnospiza maritima junicola</u>	Wakulla seaside sparrow	Special Concern	Special Concern
REPTILES			
<u>Crocodylus acutus</u>	American crocodile	Endangered	Endangered/ Critical Habitat
<u>Alligator mississippiensis</u>	American alligator	Special Concern	Threatened
<u>Dermochelys coriacea</u>	Leatherback turtle	Endangered	Endangered
<u>Chelonia mydas mydas</u>	Atlantic green turtle	Endangered	Endangered
<u>Eretmochelys imbricata imbricata</u>	Atlantic hawksbill turtle	Endangered	Endangered
<u>Lepidochelys kempi</u>	Kemp's (Atlantic) ridley turtle	Endangered	Endangered
<u>Caretta caretta caretta</u>	Atlantic loggerhead turtle	Threatened	Threatened
<u>Kinosternon bauri bauri</u>	Key mud turtle	Threatened	Threatened
<u>Chrysemys concinna suwanniensis</u>	Suwannee cooter	Special Concern	Special Concern
<u>Nerodia fusciata taeneata</u>	Atlantic salt marsh water snake	Endangered	Threatened
FISH			
<u>Acipenser brevirostrum</u>	Shortnose sturgeon	Endangered	Endangered
<u>Acipenser oxyrhynchus</u>	Atlantic sturgeon	Special Concern	Special Concern

TABLE 5.5-4
(concluded)
FLORIDA'S PROTECTED SPECIES ASSOCIATED WITH SALTWATER WETLANDS

Scientific name	Common name	Status	
		State	Federal
FISH (cont'd)			
<u>Centropomus undecimalis</u>	Common snook	Special Concern	
<u>Menidia conchorum</u>	Key silverside	Endangered	
<u>Fundulus jenkinsi</u>	Saltmarsh topmorrow	Special Concern	
<u>Rivulus marmoratus</u>	Rivulus	Special Concern	

Adapted from: FGFWFC, 1983; Pritchard, 1979; USFWS, 1982b.

Threatened - any species of fish and wildlife naturally occurring in Florida which may not be in immediate danger of extinction, but exists in such small populations as to become endangered if it is subjected to increased stress as a result of further modification of its environment.

Special Concern - any species which warrants special protection because it occurs disjunctly or continuously in Florida and has a unique and significant vulnerability to habitat modification or environmental alteration which may result in its becoming a threatened species.

In addition to the Florida Endangered and Threatened Species Act of 1977, the state has a variety of other laws and regulations designed to specifically protect species of concern, including the Endangered and Threatened Species Reward Trust Fund Act, Florida Nongame Wildlife Act, Florida Panther Act, Florida Manatee Sanctuary Act, Marine Turtles Protection Act, Bald Eagle Act and Feeding of Alligators and Crocodiles Act.

Alabama

Alabama has no specific state legislation which establishes protection for rare and endangered species. However, the Alabama Department of Conservation and Natural Resources (DCNR) accepts an unofficial list that resulted from endangered and threatened species symposia held in Alabama (Boschung, 1976). The unofficial list classifies protected species as follows:

Endangered - species in danger of extinction throughout all or a significant portion of their range in Alabama.

Threatened - those species which are likely to become endangered within the foreseeable future throughout all or a significant portion of their range in Alabama.

Special Concern - those species which must be continually monitored because of degrading factors, limited distribution or other physical or biological characteristics that may cause them to become endangered or threatened.

These species include not only permanent residents of Alabama, but also those which may be seasonally dependent on certain areas of Alabama such as coastal habitats (Table 5.5-5). Wildlife are also afforded protection by means of the Alabama Water Pollution Control Act and the Alabama Coastal Areas Act.

Mississippi

The state of Mississippi passed the Nongame and Endangered Species Conservation Act to manage and protect those species included in the United States List of Endangered Fish and Wildlife. The Mississippi Commission on Wildlife Conservation is required to maintain an official list of endangered and threatened species. The species listed are protected by state laws regulated by the Commission. The Commission defines an endangered species as one which is in danger of extinction throughout all or a significant portion of its range; and a threatened species is one which may become an endangered species within the foreseeable future in all or a significant portion of its range. Table 5.5-6 reports those species of State and Federal concern that may potentially occur in salt-water wetlands at some point in their life cycles.

The Coastal Wetlands Protection Act also assured consideration of threatened wildlife and their habitat in coastal areas. Projects affecting the state's water resources also are subject to review in accordance with the Mississippi Water Resources Act.

TABLE 5.5-5

ALABAMA'S PROTECTED SPECIES ASSOCIATED WITH SALTWATER WETLANDS

Scientific name	Common name	Status	
		State	Federal
MAMMALS			
<u>Trichechus manatus</u>	Manatee		Endangered
<u>Sylvilagus palustris palustris</u>	Marsh rabbit	Special Concern	
<u>Felis concolor coryi</u>	Florida panther	Endangered	Endangered
BIRDS			
<u>Haliaeetus leucocephalus</u>	Bald eagle	Endangered	Endangered
<u>Falco peregrinus anatum</u>	American peregrine falcon	Endangered	Endangered
<u>Falco peregrinus tundrius</u>	Arctic peregrine falcon	Endangered	Endangered
<u>Pelecanus occidentalis</u>	Brown pelican	Endangered	Endangered
<u>Pandion haliaetus</u>	Osprey	Endangered	Endangered
<u>Elanoides forficatus</u>	Swallow-tailed kite	Special Concern	Special Concern
<u>Laterallus jamaicensis</u>	Black rail	Endangered	Endangered
<u>Charadrius alexandrinus</u>	Snowy plover	Endangered	Endangered
<u>Haematopus palliatus</u>	American oystercatcher	Threatened	Threatened
<u>Dichromanassa rutescens</u>	Reddish egret	Special Concern	Special Concern
<u>Florida caerulae</u>	Little blue heron	Special Concern	Special Concern
<u>Mycticorax mycticorax</u>	Black-crowned night heron	Special Concern	Special Concern
<u>Mycteria americana</u>	Wood stork	Threatened	Threatened
<u>Anas fulvigula</u>	Mottled duck	Special Concern	Special Concern
<u>Falco columbarius</u>	Merlin		
REPTILES			
<u>Alligator mississippiensis</u>	American alligator	Threatened	Endangered
<u>Lepidochelys kempi</u>	Atlantic ridley turtle	Endangered	Endangered
<u>Chelonia mydas mydas</u>	Green turtle	Endangered	Threatened
<u>Eretmochelys imbricata</u>	Hawksbill turtle	Endangered	Endangered
<u>Dermochelys coriacea</u>	Leatherback turtle	Threatened	Endangered
<u>Caretta caretta caretta</u>	Loggerhead turtle	Endangered	Threatened

TABLE 5.5-5
(continued)
ALABAMA'S PROTECTED SPECIES ASSOCIATED WITH SALTWATER WETLANDS

Scientific name	Common name	Status	
		State	Federal
<u>FISH</u>			
<u>Acipenser oxyrhynchus</u>	Atlantic sturgeon		Threatened
<u>Scaphirhynchus</u> sp.	Alabama shovelnose sturgeon		Endangered

Adapted from: Boschung, 1976; O'Neil and Metee, 1982; USFWS, 1982b.

TABLE 5.5-6
MISSISSIPPI'S PROTECTED SPECIES ASSOCIATED WITH SALTWATER WETLANDS

Scientific name	Common name	Status	
		State	Federal
MAMMALS			
<u>Trichechus manatus</u>	Manatee	Endangered	
BIRDS			
<u>Grus canadensis pulla</u>	Mississippi sandhill crane		
<u>Haliaeetus leucocephalus</u>	Bald eagle	Endangered	Endangered
<u>Falco peregrinus tundrius</u>	Arctic peregrine falcon	Endangered	Endangered
<u>Pelecanus occidentalis</u>	Brown pelican	Endangered	Endangered
REPTILES AND AMPHIBIANS			
<u>Alligator mississippiensis</u>	American alligator	Endangered	Endangered
<u>Chelonia mydas mydas</u>	Atlantic green turtle	Endangered	Threatened
<u>Caretta caretta caretta</u>	Atlantic loggerhead turtle	Endangered	Threatened
<u>Lepidochelys kempj</u>	Kemp's (Atlantic) ridley turtle	Endangered	Endangered
<u>Eretmochelys imbricata</u>	Hawksbill turtle		
<u>Dermochelys coriacea</u>	Leatherback turtle	Endangered	Endangered
FISH			
<u>Acipenser oxyrhynchus</u>	Atlantic sturgeon	Endangered	

Adapted from: Mississippi Department of Wildlife Conservation Bureau of Fisheries and Wildlife,
Public Notice No. 2156; and USFWS, 1982b.

5.5.6 Impacts to Wildlife from Wastewater Application

The wildlife community of a saltwater-wetland ecosystem may be altered due to managed wastewater application. The potential for change is dependent on many interrelated biological, physical and chemical characteristics of the wetland system. Impacts of wastewater on a wetland also will vary according to how the wastewater system is designed, installed and maintained, and the type of wastewater that is applied.

Quantifiable data concerning the wildlife components of treated saltwater wetlands are not available. However, impacts on wildlife may be expected to result from altered flow and salinity rates, composition of vegetation, and the availability of food. The biological, physical and chemical mechanisms in saltwater wetlands that are involved in wastewater management are so interrelated that their effects are often inseparable. Changing the water level and introducing freshwater into a saltwater marsh may force changes in the vegetative regime. Altering the species composition within the plant community may, in turn, affect wildlife species abundance and diversity. Animal populations will change as a result of food and habitat alterations. The aquatic community also may be affected by changes in salinity rates due to the addition of fresh water. Tidal fluctuations and runoff can transport the fresh water, affecting fish populations. Potential changes in the availability of commercially important fish and shellfish may have economic and recreational ramifications.

Discharge of treated effluent from municipal or seafood-processing waste systems to saltwater wetlands may change the water quality of the wetland and impact the associated wildlife. The nutrients in the wastewater increases the productivity of the marsh vegetation and the nutrient content of the plant tissues. The productivity of the entire marsh estuarine system could therefore eventually be increased (Fowler et al., no date). A potential problem from sewage effluent is the concentration of materials such as hydrocarbons and heavy metals in the sediment, which causes a build-up of toxic substances that are detrimental to productivity (Fowler et al., no date; Hammer and Kadlec, 1983). The extent of the transfer of metals in the food chain depends upon the metal, its form, and the extent to which the particular chemical is translocated to plant parts that are either consumed directly by herbivores (mainly insects) or broken down and consumed as detritus. Fish and filter feeders may absorb metals directly from the water, (Giblin et al., 1980)..

The ultimate fate and effects of introducing toxic substances into wetlands, the potential for transferring these substances through both detrital and direct-consumption food webs, and of concentrating them in sensitive species are not well studied. Some estuarine organisms do have mechanisms for dealing with high concentrations of metals and other compounds. Hammer and Kadlec (1983) report that oysters can produce vacuoles of crystalline metal salts that isolate such compounds from their metabolic system. Crustaceans can transfer environmental pollutants or metabolic by-products into their exoskeleton, which is shed

periodically. It is not known whether the pollutants in the chitinous exoskeleton can be transferred to higher consumers (e.g., fish), since chitin is not a digestible material (Hammer and Kadlec, 1983). The question of how much metal contamination can occur before an ecosystem is damaged remains unanswered.

Wildlife impacts can also occur as a result of absorption by plants and invertebrates of viral and bacterial pathogens from sewage effluent. It can only be speculated that viral/bacterial diseases would be transmitted throughout various levels of the food chain. Long-term studies in saltwater-wetland systems being used for treated sewage or seafood processing wastewater application are not available.

There is a clear need for information on the effects of wastewater discharge on saltwater wetlands and wildlife and the potential for transferring contaminants through food webs. General estimates of beneficial and adverse effects on wildlife populations and habitats may be inferred from freshwater studies and from a few saltwater studies (USACOE, 1977). Techniques to evaluate the impacts are being developed. Baseline studies, conducted prior to a proposed discharge, provide a comparison with monitoring studies conducted during the discharge into a saltwater wetland. Baseline quantitative data also may be derived from state water-quality monitoring data reports. Other sources of baseline information include existing literature reviews, field studies, and/or laboratory research. Mathematical modeling and ecosystem simulation can assist in evaluating assumptions and determining data needs.

Biological specimens are often qualitatively or quantitatively collected and taxonomically identified to establish an ecological baseline for a given site. Vegetation surveys of wetland areas are useful to determine existing species, especially any rare and endangered species. Animal populations can be evaluated through observation and counts (e.g., birds), entrapment (e.g., small mammals), tagging (mark and recapture for fish and wildlife), and sampling (e.g., benthic communities). Fish species can be sampled with seines, traps and trawls. Species diversities are also calculated to determine the "health" of a community or the effects of wastewater application to a wetland. Field sampling methodologies may be obtained from the literature of the USEPA, U.S. Geological Survey, and most university libraries. Long-term site specific analyses would have to be performed to provide the data necessary to assess the impacts on wildlife of managed wastewater discharges into saltwater wetlands.

5.6 SCIENTIFIC FACTORS RELATED TO WASTEWATER MANAGEMENT IN SALTWATER WETLANDS

The saltwater-wetland components described in the previous sections had several variable and interrelated characteristics, functions and processes that could potentially be impacted by municipal or seafood-processing wastewater discharges. Potential effects could be negative or positive, depending upon the site and the type of impact being considered. The unique quality of each wetland is discussed in a review article which describes five basic orders of magnitude of wetland impacts and 13 ecological and public-interest variables that can modify the basic

impact (Nelson and Weller, 1984). The authors do not limit their analyses to saltwater wetlands and discuss a broader range of potential impacts than wastewater discharge alone but the consequences of wetland alteration that Nelson and Weller describe provide an overview of the issues discussed here.

A summary of the previous sections in this chapter indicates that there are five major factors to be considered when evaluating the potential impacts of wastewater discharges in saltwater wetlands: erosion, nutrients, toxic substances, vegetation and wildlife.

5.6.1 Erosion

Erosion would be expected to vary with characteristics of the soil, including sediment composition (porosity) and percentage water saturation, with the density of vegetation and with velocity of the discharge and the method of application. Erosion would probably be most severe in relatively high, sparsely vegetated marshes. Erosion could result in materials washed from one area of the marsh causing sedimentation in another area; for example, from a high marsh to a low marsh. Conversely, nutrients in the effluent could stimulate growth of vegetation to the point where erosion was decreased. Finally, sediments resulting from erosion that are trapped by vegetation within the marsh may eventually lead to a change in the species composition of the marsh community.

Areas subject to erosion would require low application levels of effluent discharge and correspondingly large areas of marsh for erosion

control. Rates of effluent application and the amount of marsh area that would be considered adequate for receiving different effluent volumes are not known at this time and would require site-specific evaluation.

5.6.2 Nutrients

Treated wastewater would provide a source of nutrients that may have an effect on wetland marsh vegetation and on the estuarine receiving waters. The primary consideration regarding nutrients is that the absorbing capacity of the wetlands not be exceeded. In other words, nutrients must be taken up by the soil or vegetation prior to tidal inundation. If uptake has not occurred prior to flooding, a wetland discharge would be equivalent to direct discharge into the estuary.

Nutrient uptake in wetland sediments is dependent on soil sediment composition and percentage water saturation. Lower marshes are composed of fine sand, clay and organic deposits, are characterized by a water table near the surface and are less permeable than the high marshes or upland soils. Similarly, lower marshes would be inundated by tidal flooding more frequently and over longer periods of time. It would thus appear that the higher marshes provide for a greater period of time for nutrient uptake than do lower marshes. However, site-specific studies would still be needed to determine sediment characteristics and hydrologic parameters that could affect the flushing of nutrients from wastewater effluent into adjacent estuarine waters. Additionally, studies are required to estimate nutrient uptake by vegetation within the marsh. Particular emphasis would be on whether nutrients from wastewater

effluent would be beneficial, detrimental or of no effect when supplemental to naturally occurring nutrients.

5.6.3 Toxic Substances and Pathogens

Toxic substances, metals and pathogens are potentially relevant to municipal and/or seafood-processing wastewater discharges. As occurred with nutrients, the absorbing capacity of the wetland must not be overloaded or filtering capacity is lost and it is then equivalent to direct discharge into the estuary. There are additional concerns with the toxic substances and pathogens however, that are not of concern with nutrients. Most of these concerns are related to 1) how metals are tied up in the sediments or released from the sediments, 2) how metals are absorbed by plants and transferred through detrital and direct-consumption food webs, 3) how long pathogens (bacterial or viral) will remain viable in the sediments and 4) whether pathogens would be absorbed by plants and/or otherwise passed up the food chain. These questions are particularly relevant for consideration because they may affect public health.

5.6.4 Vegetation

Depth and regularity of tidal flooding are the primary factors that determine vegetation species composition and distribution in a salt marsh; salinity is the primary factor in a brackish marsh. Each of these primary factors may be altered by wastewater discharge to a saltwater wetland. Potential changes include decreased salinity resulting from the effluent being primarily freshwater, continual saturation of soil sedi-

ments, and upsetting the natural seasonal variation in the moisture cycle within the marsh. Any of these changes could lead to shifts in the marsh vegetation. For example, if salinity in a saltwater marsh was decreased for any extended period of time, colonization by plant species adapted to fresh or brackish-water habitats would be expected to occur. On the other hand, in a hydrologically-depleted wetland that has been altered by dikes or channelization, application of treated wastewater could potentially re-establish marsh vegetation, even though it may not be the same plant species that occurred there originally.

Nutrient uptake by vegetation was previously mentioned as an area requiring additional study. Vegetation has the potential for removing and using the nutrients from wastewater and, particularly in areas where nutrients may be limited, the potential for increased plant productivity. There is also the possibility that the nutrients added by wastewater application could extend the growing season, further enhancing productivity.

5.6.5 Wildlife

One of the potential effects on wildlife of wastewater discharges in saltwater wetlands would be primarily indirect, resulting from the altered flow and salinity effects on the vegetation. Animal species composition and distribution would be expected to change if vegetation patterns changed because differences would then occur in food availability, nesting sites, cover and similar habitat parameters.

Effects on wildlife resulting from toxic substances and pathogens could be either direct or indirect. For example, pathogens may affect animals directly, whereas metals would take a more circuitous route through the food chain. As previously mentioned, several questions are yet to be answered about the potential effects of toxic substances and pathogens.

5.7 LITERATURE CITED

- Adams, D.A. 1963. Factors influencing vascular plant zonation in North Carolina salt marshes. *Ecology* 44: 445-456.
- Association of Bay Area Governments. 1982. The use of wetlands for water pollution control. Prepared for the Municipal Environmental Research Laboratory, Cincinnati. PB83-107466.
- Beccasio, A.D., G.H. Weissberg, A.E. Redfield et al. 1980. Atlantic Coast ecological inventory: User's guide and information base. Biological Services Program, U.S. Fish and Wildlife Service. Washington, D.C. 163 pp.
- Beccasio, A.D., N. Fotheringham, A.E. Redfield et al. 1982. Gulf Coast ecological inventory: User's guide and information base. Biological Services Program, U.S. Fish and Wildlife Service. Washington, D.C. 191 pp.
- Beeftink, W.G., M.C. Daane, J.M. Van Liere and J. Nieuwenhuize. 1977. Analysis of estuarine soil gradients in salt marshes of the Southwestern Netherlands with special reference to the Scheldt Estuary. *Hydrobiologia* 52(1):93-106.
- Bender, M.E. and D.L. Correll. 1974. The use of wetlands as nutrient removal systems. National Technical Information Service, U.S. Dept. of Commerce. 12 pp.
- Blanton, J.O. and L.P. Atkinson. 1978. Physical transfer processes between Georgia tidal inlets and nearshore waters. M.L. Wiley, editor. Academic Press, New York.
- Boschong, Herbert (ed.) 1976. Endangered and threatened plants and animals of Alabama. Bulletin, Alabama Museum of Natural History. Number 2: 93 pp.
- Brooks, R.R. 1977. Pollution through trace elements. Pages 429-447 in J.O. Bockris, (ed.). *Environmental Chemistry*. Plenum Press, New York.
- Brown and Caldwell Consulting Engineers. 1982. Preliminary design and marine survey for ocean outfall: Dare County, North Carolina. Final Report. Prepared in association with Law Engineering Testing Company. Funded in part by the USEPA, Region IV.
- Burrell, V.C., Jr. 1975. The relationship of proposed offshore nuclear power plants to marine fisheries of the south Atlantic region of the United States. In: *Procedures Ocean 1975 Conference*, San Diego, CA. (cited in Sandifer et al., 1980).

LITERATURE CITED (continued)

- Caspers, H. 1967. Estuaries: analysis of definitions and biological considerations. Pages 6-8 in G.H. Lauff, (ed). Estuaries. American Association for the Advancement of Science, Washington, D.C.
- Chapman, V.J. 1938. Studies in salt marsh ecology. In: Journal of Ecology 26:144-179.
- Chapman, V.J. 1974. Salt marshes and salt deserts of the world. Verlag von J. Cramer. New York. pg 52.
- Clark, J. 1974. Coastal ecosystems: Ecological considerations for management of the coastal zone. The Conservation Foundation, Washington, D.C. 178 pp.
- Daiber, F.C. 1972. Tide marsh ecology and wildlife: saltmarsh plants and future coastal salt marshes in relation to animals. 1971-1972 Annual Pittman-Robertson Report to Division of Fish and Wildlife, Dept. of Natural Resources and Environmental Control, State of Delaware. 80 pp.
- Daiber, F.C. 1977. Salt-marsh animals: distributions related to tidal flooding, salinity and vegetation. Pages 79-108 in V.J. Chapman (ed.). Wet Coastal Ecosystems. Elsevier Scientific Publishing Company, Amsterdam.
- Davis, J.H., Jr. 1940. The ecology and geologic role of mangroves in Florida. Carnegie Institute, Washington, D.C. Publication 517. Tortugas Laboratory Paper 3: 113-195.
- de la Cruz, A.A. 1981. Differences between South Atlantic and Gulf Coast marshes. Pages 10-20 in R.C. Carey, P.S. Markovits and J.B. Kirkwood, eds. Proceedings U.S. Fish and Wildlife Service Workshop on Coastal Ecosystems of the Southeastern United States. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C. FWS/OBS-80/59. 257 pp.
- Deacon, J.E., G. Kobetich, J.D. Williams et al. 1979. Fishes of North America endangered, threatened, or of special concern: 1979. Prepared for U.S. Fish and Wildlife Service by the American Fisheries Society. 4(2): 29-44.
- Dvorak, A.G. (ed.). 1978. Impacts of coal-fired power plants on fish, wildlife, and their habitats. National Power Plant Team, U.S. Fish and Wildlife Service. Ann Arbor, Mich. 261 pp.
- Ellender, R.D., D.W. Cook, V.L. Sheladia and R.A. Johnson. 1980. Enterovirus and bacterial evaluation of Mississippi oysters. Gulf Research Reports 6(4):371-376.

LITERATURE CITED (continued)

- Emery, K.O. 1967. Estuaries and lagoons in relation to continental shelves. Pages 9-11 in G.H. Lauff, (ed.). Estuaries. American Association for the Advancement of Science, Washington, D.C.
- Engel, D.W., W.G. Sunda and B.A. Fowler. 1981. Factors affecting trace metal uptake and toxicity to estuarine organisms. I. Environmental parameters. Pages 127-144 in F.J. Vernberg, A. Calabrese, F.B. Thurberg and W.B. Vernberg (eds.). Biological Monitoring of Marine Pollutants. Academic Press, Inc.
- Engels, W.L. 1952. Vertebrate fauna of North Carolina coastal islands. II. Shackleford Banks. American Midland Naturalist 47(3): 702-742. (cited in Sandifer et al., 1980).
- Florida Game and Fresh Water Fish Commission (FGFWFC). 1983a. Endangered and potentially endangered fauna and flora in Florida, official lists, 1 March 1983. Florida Game and Fresh Water Fish Commission. Tallahassee, FL.
- Florida Game and Fresh Water Fish Commission (FGFWFC). 1983b. Laws and regulations affecting endangered and potentially endangered species in Florida, 15 July 1983. Florida Game and Fresh Water Fish Commission. Tallahassee, FL. 16 pp.
- Fowler, Bruce A., N.G. Carmichael, K.S. Squibb et al. no date. Factors affecting trace metals uptake and toxicity to estuarine organisms II. Cellular mechanisms. S.E.F.C. Contribution No. 80-53B. 163 pp.
- Gallagher, J.L. 1971. Algal Productivity and Some Aspects of the Ecological Physiology of the Edaphic Communities of Canary Creek Tidal Marsh. Ph.D. Dissertation. Univ. of Delaware, Newark, Del. 120 pp.
- Gallagher, J.L. 1974. Sampling macro-organic matter profiles in salt marsh plant root zones. Soil Science Society of America. Proceedings. 38:154-155 (cited in Gallagher et al., 1977).
- Gallagher, J.L. and R.J. Reimold. 1973. Tidal marsh plant distribution and productivity patterns from the sea to fresh water - a challenge in resolution and discrimination. In: Aerial Color Photography in the Plant Sciences and Related Fields. Proceedings Fourth Biennial Workshop on Aerial Color Photography in the Plant Sciences. American Society of Photogrammetry. University of Maine. Orono. pp. 165-185. In C.H. Wharton. 1978. The Natural Environments of Georgia. Georgia Department of Natural Resources.

LITERATURE CITED (continued)

- Gallagher, J.L., F.G. Plumley and P.L. Wolf. 1977. Underground biomass dynamics and substrate selective properties of Atlantic coastal salt marsh plants. University of Georgia Marine Institute. Office Chief of Engineers, U.S. Army, Dredged Material Research Program, Technical Report D-77-28, Washington, D.C. 131 pp.
- Gallagher, J.L., R.A. Linthurst and R.J. Reimold. 1975. Marshes of McIntosh County, Georgia. Unpublished manuscript. University of Georgia, Marine Institute, Sapelo Island, Georgia. 8 pp. and map. In C.H. Wharton. 1978. The Natural Environments of Georgia. Georgia Department of Natural Resources.
- Gates, K.W., B.E. Perkins, J.G. EuDaly, A.S. Harrison and W.A. Bough. 1982. Assessment of seafood processing and packing plant discharges and their impacts on Georgia's estuaries. Georgia Marine Science Center. Technical Report Series, Number 82-3. University of Georgia Marine Extension Service, Brunswick, Georgia. 106 pp.
- Giblin, A.E., A. Bourg, I. Valiela and J.M. Teal. 1980. Uptake and losses of heavy metals in sewage sludge by a New England salt marsh. American Journal of Botany 67(7):1059-1068.
- Gooch, E.L. 1968. Hydrogen sulfide production and its effect on inorganic phosphate release from the sediments of Canary Creek Marsh. M.S. Thesis, Univ. of Delaware. (cited in Daiber, F.C. 1972.)
- Gosselink, J.G., C.L. Cordes and J.W. Parsons. 1979. An ecological characterization study of the Chenier Plain coastal ecosystem of Louisiana and Texas. U.S. Fish and Wildlife Service. FWS/OBS-78/9 through 78/11. 3 vols.
- Gosselink, J.G., E.P. Odum and R.M. Pope. 1974. The value of the tidal marsh. Center for Wetland Resources, Louisiana State University, Baton Rouge, LA. LSU-SG-74-03. 30 pp.
- Gresson, P.E., J.R. Clark. and J.E. Clark. 1978. Wetland functions and values: The state of our understanding. Proceedings of the National Symposium on Wetlands. American Water Resources Association.
- Guilcher, A. 1967. Origin of sediments in estuaries. Pages 149-157 in G.H. Lauff, (ed.). Estuaries. American Association for the Advancement of Science, Washington, D.C.
- Gulf South Research Institute. 1977. Coastal marsh productivity: A bibliography. Fish and Wildlife Service, U.S. Department of the Interior. FWS/OBS-77/3. U.S. Government Printing Office, Washington, D.C. 300 pp.

LITERATURE CITED (continued)

- Gunter, G. 1961. Some relations of estuarine organisms to salinity. *Limnology and Oceanography* 6(2): 182-190. (cited in O'Neil and Mettee, 1982).
- Gusey, W.F. 1981. The fish and wildlife resources of the south Atlantic Coast. Shell Oil Company, Environment Affairs, Houston, TX.
- Haines, E.B. 1979. Growth dynamics of cordgrass, Spartina alterniflora Loisel., on control and sewage sludge fertilized plots in a Georgia salt marsh. *Estuaries* 2(1):50-53.
- Hammer, D.E. and R.H. Kadlec. 1983. Design principles for wetland treatment systems. USEPA 600/2-83-026. Ada, OK.
- Hardisky, M.A., R.M. Smart and V. Klemas. 1983. Growth response and special characteristics of a short Spartina alterniflora salt marsh irrigated with freshwater and sewage effluent. *Remote Sensing of Environment*. 13:57-67.
- Hinde, H.P. 1954. The vertical distribution of salt marsh phanerogams in relation to tide levels. *Ecological Monographs*. 24:209-225.
- Horwitz, E.L. 1978. Our nation's wetlands: An interagency task force report. U.S. Government Printing Office, Washington, D.C. 70 pp.
- Hoyt, J.H. 1967. Barrier island formation. *Geological Society of American Bulletin*. 78(9):1125-1136.
- Hoyt, J.H. 1968. Geology of the Golden Isles and lower Georgia coastal plain. Pages 18-34 in D.S. Maney, F.C. Marland and C.B. West, (eds.). *Conference on the future of the marshlands and sea islands of Georgia*. October 13-14, 1968. Georgia Natural Areas Council and Coastal Area Planning and Development Committee.
- Humm, H.J. 1973. Salt marshes. In Jones, J.I., R.E. Ring, M.O. Rinkel and R.E. Smith, (eds.). *A summary of knowledge of the eastern Gulf of Mexico*. University of Florida Institute of Oceanography. St. Petersburg, FL.
- Kilgore, W.W. and M.-Y. Li. 1980. Food additives and contaminants. Pages 593-607 in J. Doull, C.D. Klaassen and M.O. Amdur (eds.). *Casarett and Doull's Toxicology - The Basic Science of Poisons*. Second Edition. Macmillan Publishing Co., Inc., New York. 778 pp.
- Lee, C.R., R.E. Hoeppel, P.G. Hunt and C.A. Carlson. 1976a. Feasibility of the functional use of vegetation to filter, dewater, and remove contaminants from dredged material. Technical Report D-76-4. Dredged Material Research Program, U.S. Army Engineer Waterways Experiment Station. Vicksburg, MS. 34 pp with appendices.

LITERATURE CITED (continued)

- Lee, C.R., T.C. Sturgis and M.C. Landin. 1976. A hydroponic study of heavy metal uptake by selected marsh plant species. U.S. Army Engineer Waterways Experiment Station. Vicksburg, MS. Technical Report D-76-5.
- Lee, C.R., T.C. Sturgis and M.C. Landin. 1976b. A hydroponic study of heavy metal uptake by selected marsh plant species. Technical Report D-76-5. Dredged Material Research Program, U.S. Army Engineer Waterways Experiment Station. Vicksburg, MS. 47 pp. with tables and appendix.
- Linton, T.L. 1968. A description of the south Atlantic and Gulf coast marshes and estuaries. pp 1-25. In J.D. Newson (ed.), *Proceedings of Marsh and Estuary Management Symposium*. Louisiana State University, Baton Rouge.
- Long, S.P. and C.F. Mason. 1983. *Saltmarsh ecology*. Blackie and Son, Glasgow. 160 pp.
- Lugo, A.E. and S.C. Snedaker. 1974. The ecology of mangroves. *Annual Review of Ecology and Systematics*. 5:39-64.
- Mathews, T.D., F.W. Stapor, C.R. Richter et al., (eds.). 1980. Ecological characterization of the Sea Island region of South Carolina and Georgia. Vols. I-III. FWS/OBS-79/40, 41 and 42.
- Metcalf and Eddy, Inc. 1979. *Wastewater Engineering: Treatment/Disposal/Reuse*. McGraw-Hill. New York.
- National Wetlands Technical Council. 1978. *Scientist's report. National Symposium on Wetlands*. Lake Buena Vista, Florida, 6-9 November 1978. 127 pp.
- Neill, W.T. 1958. The occurrence of amphibians and reptiles in salt-water areas, and a bibliography. *Bulletin of Marine Sciences Gulf Caribbean* 8(1): 1-97. (cited in Sandifer et al., 1980).
- Nelson, R.W. and E.C. Weller. 1984. A better rationale for wetland management. *Environmental Management*. Vol. 8, No. 4, Springer-Verlag New York Inc., New York. pp. 295-308.
- Nichols, D.S. 1983. Capacity of natural wetlands to remove nutrients from wastewater. *Journal Water Pollution Control Federation*. 55(5):495-505.
- Nixon, S.W. 1982. The ecology of New England high salt marshes: a community profile. U.S. Fish and Wildlife Service, Office of Biological Services. FWS/OBS-81/55. Washington, D.C. 70 pp.
- O'Neil, P.E. and M.F. Mettee. 1982. Alabama coastal region ecological characterization. Volume 2. A synthesis of environmental data. U.S. Fish and Wildlife Service, Office of Biological Services. FWS/OBS-82/42. Washington, D.C. 346 pp.

LITERATURE CITED (continued)

- Odum, E.P. 1971. Fundamentals of ecology. 3rd ed. W.B. Saunders Company, Philadelphia, PA. 574 pp.
- Odum, E.P. and A.A. de la Cruz. 1967. Particulate organic detritus in a Georgia salt marsh - estuarine ecosystem. pp 383-388 in G. Lauff (ed.). Estuaries. American Association for the Advancement of Sciences. Publication 83, Washington, D.C.
- Odum, H.T., B.J. Copeland and E.A. McMahan (Eds.). 1974. Coastal ecological systems of the United States. Volume II. The Conservation Foundation and the National Oceanic and Atmospheric Administration. 521 pp.
- Odum, H.T., K.C. Ewel, J.W. Ordway and M.K. Johnston. 1975. Cypress wetlands for water management, recycling and conservation. Second Annual Report to National Science Foundation. Center for Wetlands, Phelps Lab, University of Florida. Gainesville, FL. 817 pp.
- Odum, Ron R., J.L. McCollum, M.A. Neville and D.R. Ettman. 1977. Georgia's protected wildlife. Game and Fish Division, Engangered Wildlife Program, Georgia Department of Natural Resources, Social Circle, GA. 51 pp.
- Odum, W.E. 1970. Utilization of the direct grazing and plant detritus food chains by the striped mullet Mugil cephalus. In: J. Steele (ed.). Marine food chains, a symposium. University of California Press, Berkeley, CA. (cited in Sandifer et al., 1980).
- Odum, W.E., C.C. McIvor and T.J. Smith. 1982. The ecology of the mangroves of South Florida: a community profile. Bureau of Land Management, Fish and Wildlife Service, U.S. Department of the Interior. FWS/OBS-81/24. U.S. Government Printing Office, Washington, D.C. 144 pp.
- Odum, W.E., J.S. Fisher and J.C. Pickral. 1979. Factors controlling the flux of particulate organic carbon from estuarine wetlands. Pages 69-80 in R.J. Livingston, (ed.). Ecological processes in coastal and marine systems. Plenum Press, New York.
- Oertel, G.F. 1975. Post Pleistocene island and inlet adjustment along the Georgia coast. Journal of Sedimentary Petrology 45(1):150-159.
- Oertel, G.F. and J.D. Howard. 1972. Water circulation and sedimentation at estuary entrances on the Georgia coast. Pages 411-427 in D.J.P. Swift, D.B. Duane, and O.H. Pilkey, (eds.). Shelf sediment transport: process and pattern. Dowden, Hutchinson and Ross, Inc., Stroudsburg, PA.

LITERATURE CITED (continued)

- Olsen, E.J. 1977. A study of the effects of inlet stabilization at St. Mary's Entrance, Florida. Pages 311-329 in Coastal sediments '77. Fifth Symposium of the Waterway, Port, Coastal and Ocean Division. American Society of Civil Engineers. New York.
- Parker, W. and L. Dixon. 1980. Endangered and threatened wildlife of Kentucky, North Carolina, South Carolina and Tennessee. U.S. Fish and Wildlife Service and North Carolina Agricultural Extension Service. Raleigh, NC. 122 pp.
- Penfound, W.T. 1952. Southern swamps and marshes. Botanical Review 18: 413-446.
- Peterson, C.H. and N.M. Peterson. 1979. The ecology of intertidal flats of North Carolina: a community profile. U.S. Fish and Wildlife Service, Office of Biological Services. Washington, D.C. FWS/OBS-79/39. 73 pp.
- Phleger, F.B. 1977. Soils of marine marshes. Pages 69-77 in V.J. Chapman (ed.). Wet Coastal Ecosystems. Elsevier Scientific Publishing Company. Amsterdam.
- Postma, H. 1967. Sediment transport and sedimentation in the estuarine environment. Pages 158-179 in G.H. Lauff (ed.). Estuaries. American Association for the Advancement of Science. Washington, D.C.
- Pritchard, D.W. 1967. What is an estuary: physical viewpoint. Pages 3-5 in G.H. Lauff (ed.). Estuaries. American Association for the Advancement of Science. Washington, D.C.
- Pritchard, P.C. (Ed.). 1978. Rare and endangered biota of Florida. Volumes I-IV (1982). Published for Florida Game and Fresh Water Fish Commission. University Presses of Florida, Gainesville, FL.
- Rabalais, N.N. 1980. Ecological values of selected coastal habitats. In P.L. Fore and R.D. Peterson (eds.). Proceedings of the Gulf of Mexico coastal ecosystems workshop. U.S. Fish and Wildlife Service. FWS/OBS-80/30.
- Redfield, A.C. 1967. The ontogeny of a salt marsh estuary. Pages 108-114 in G.H. Lauff (ed.). Estuaries. American Association for the Advancement of Science. Washington, D.C.
- Reid, G.K. 1961. Ecology of inland waters and estuaries. Van Nostrand Reinhold Company, New York. 375 pp.

LITERATURE CITED (continued)

- Rusnak, G.A. 1967. Rate of sediment accumulation in modern estuaries. Pages 180-184 in G.H. Lauff, (ed.). Estuaries. American Association for the Advancement of Science. Washington, D.C.
- Russell, R.J. 1967. Origin of estuaries. Pages 93-99 in G.H. Lauff (ed.). Estuaries. American Association for the Advancement of Science. Washington, D.C.
- Sandifer, P.A., J.V. Miglanese, D.R. Calder et al., 1980. Ecological characterization of the Sea Island coastal region of South Carolina and Georgia. Volume III: Biological features of the characterization area. U.S. Fish and Wildlife Service, Office of Biological Services. Washington, D.C. FWS/OBS-79/42. 629 pp.
- Schelske, C.L. and E.P. Odum. 1962. Mechanisms maintaining high productivity in Georgia estuaries. Gulf and Caribbean Fisheries Institute Procedures 14: 75-8. (cited in Sandifer et al., 1980).
- Sharp, H.F., Jr. 1962. Trophic relationships of the rice rat, Oryzomys palustris palustris (Harlan), living in a Georgia saltmarsh. M.S. Thesis. University of Georgia, Athens. (cited in Sandifer et al., 1980).
- Smalley, A.E. and L.B. Thien. 1976. Effects of environmental changes on marsh vegetation with special reference to salinity. Final report. Tulane University.
- Smith, J.O. 1978. Preservation of endangered species through state law in: R.R. Odum and L. Landers (eds.). Procedures of the Rare and Endangered Wildlife Symposium. Georgia Department of Natural Resources. Technical Bulletin WL4.
- Stapor, F.W. and R.S. Murali. 1978. Computer modeling of littoral sand transport (shore-parallel) for coastal South Carolina. S.C. Marine Resources Center Technical Report No. 29. 9 pp.
- Sullivan, M.J. 1971. Distribution and Ecology of Edaphic Diatoms in the Canary Creek Salt Marsh. M.S. Thesis. Univ. of Delaware, Newark, Del. 95 pp.
- Taylor, J.L. 1973. Biological studies and inventory for the Tampa Harbor, Florida project. Taylor Biological Company. 101 pp.
- Teal, J. and M. Teal. 1969. Life and Death of the Salt Marsh. National Audubon Society/Ballantine Books, Inc., New York. 274 pp.
- Teal, J.M. and I. Valiela. 1973. The salt marsh as a living filter. Marine Technology Society Journal 7:19-21.

LITERATURE CITED (continued)

- U.S. Army Corps of Engineers. 1977. New Orleans - Baton Rouge metropolitan area, Louisiana water resources study. Wastewater treatment by marsh application work report. Submitted to Department of the Army, New Orleans District Corps of Engineers.
- U.S. Fish and Wildlife Service (USFWS). 1982a. Central Gulf coast wetlands, migratory bird habitat preservation program. Prepared for USEPA Region IV, Atlanta, GA. 103 pp.
- U.S. Fish and Wildlife Service (USFWS). 1982b. Federally listed endangered and threatened species by state: Alabama, Florida, Georgia, Mississippi, North Carolina, South Carolina. U.S. Department of the Interior, Washington, D.C.
- United States Environmental Protection Agency. 1983. Environmental impact statement, Phase 1 report, freshwater wetlands for wastewater management. EPA 904/9-83-107. 380 pp.
- Valiela, I., J.M. Teal and W. Sass. 1973. Nutrient retention in salt marsh plots experimentally fertilized with sewage sludge. *Estuarine and Coastal Marine Science* 1:261-269.
- Valiela, I., J.M. Teal, C. Cogswell, J. Hartman, S. Allen, R. Van Etten and D. Goehringer. 1982. Proceedings of the workshop on ecological considerations in wetland treatment of wastewater. Amherst, MA.
- Valiela, I., J.M. Teal, C. Cogswell, J. Hartman, S. Allen, R. Van Etten and D. Goehringer. Unpublished. Some long-term consequences of sewage contamination in salt marsh ecosystems. Presented at the Proceedings of the Workshop on Ecological Considerations in Wetland Treatment of Wastewater, 23-25 June 1982, Amherst, MA.
- Valiela, I., J.M. Teal, S. Volkman, D. Shafer and E.J. Carpenter. 1978. Nutrients and particle fluxes in a salt marsh ecosystem: Tidal exchanges and inputs by precipitation and ground water. *Limnology and Oceanography* 23:798-812.
- Vernberg, F.J., A. Calabrese, F.P. Thurberg and W.B. Vernberg, (eds.). 1981. Biological monitoring of marine pollutants. Academic Press, Inc.
- Ward, L.G. 1979. Hydrodynamics and sediment transport in a salt marsh tidal channel. Proceedings of the Sixteenth Coastal Engineering Conference, ASCE.
- Weber, W.J. Jr. 1972. Physicochemical Processes for Water Quality Control. Wiley-Interscience. New York. 640 pp.

LITERATURE CITED (continued)

- Zedler, J. 1982. Wastewater input to coastal wetlands: management concerns. Pages 203-216 in P.J. Godfrey, E.R. Kaynor and J. Benforado (eds.). Proceedings of a workshop on Ecological Considerations in Wetlands Treatment of Municipal Wastewater, June 1982, Amherst, Massachusetts (Draft manuscript).
- Zedler, J. 1983. Freshwater impacts in normally hypersaline marshes. *Estuaries* 6:346-355.
- Zieman, J.C. 1982. The ecology of the seagrasses of South Florida: a community profile. U.S. Fish and Wildlife Service. FWS/OBS-82/85.

6.0 ENGINEERING CONSIDERATIONS

Facilities planning, design, and operational considerations associated with discharging wastewater to a saltwater wetland are discussed in this chapter. Many of these considerations are similar to those discussed elsewhere for freshwater wetlands; those unique to saltwater wetlands are highlighted. Specific, reliable design criteria for wastewater loading rates and water depths in wetlands and for other engineering parameters have not been developed due largely to the geographic variability of wetlands, lack of data, and wetland system complexities. Seafood-processing wastewaters differ from municipal wastewaters in flow and quality characteristics. The effects of discharging seafood-processing wastewaters to saltwater wetlands have apparently not been investigated, judging from information collected and evaluated in this effort.

The objective of this chapter is to discuss a wide range of engineering factors relevant to municipalities and industries that discharge wastewater to saltwater wetlands. Many of these factors are also important for freshwater wetland wastewater systems. The reader is referred to Chapter 6 of the Phase I Report for the Freshwater Wetlands for Wastewater Management EIS (U.S. EPA, February 1983) for a more detailed discussion of options suitable for both freshwater and saltwater systems.

Both natural and artificially-created wetlands can be used for management of municipal wastewaters. In fact, much more is known about the design and performance of artificial wetland wastewater systems than about natural systems. However, artificial systems are less applicable to saltwater than freshwater wetlands, because little or no research has been conducted with artificial systems in which salinity or tidal flows

have been regulated. Tidal flatlands, however, have been used to create freshwater artificial systems (U.S. EPA, September 1979).

Sludge management is not included in this report because sludge can not be discharged to wetland systems due to their designation as "waters of the United States" (see discussion in Chapter 4.0).

Issues of Interest

- . What are the engineering considerations important to planning, designing, implementing, operating, and maintaining a saltwater wetland for wastewater management?
- . How applicable is past research with freshwater wetland wastewater systems to saltwater wetland wastewater systems?
- . Are specific design criteria for saltwater wetland wastewater systems available?
- . To what extent is monitoring of system performance useful?

6.1 MANAGEMENT OF MUNICIPAL WASTEWATERS UTILIZING SALTWATER WETLANDS

In this section planning, design, construction, operation-maintenance-repair, and monitoring are discussed for secondary-treated municipal wastewaters discharged to a wetland. The reasons for secondary treatment prior to discharge are given in Chapter 4.0.

The water quality characteristics of typical secondary-treated municipal wastewater from a coastal area are listed in Tables 6.1-1 and 6.1-2. Some marine water quality characteristics also are presented in Tables 6.1-1 and 6.1-2 for comparison with treated wastewater characteristics. Concentrations of metals and organic compounds in treated

TABLE 6.1-1

QUALITY GUIDELINES, MARINE WATER QUALITY AND TYPICAL
EFFLUENT QUALITY FOR SELECTED CONSTITUENTS^a

<u>Constituent</u>	<u>Most Stringent Quality Guideline</u>	<u>Typical Seawater</u>	<u>Secondary Effluent</u>
Ammonia-nitrogen	270 @ 30°C pH 8.0	-	-
Cadmium (total)	3	0.1	10
Chlorine residual	2	-	-
Chlorinated hydro- carbon (total)	2	-	-
Chromium	2	0.5	90
Fecal coliforms	14 (shellfish) 200 (bathing)	- -	- -
Copper	5	3	50
Cyanide	5	-	10
Lead	8	0.03	20
Manganese	100	2	50
Mercury	0.10	0.05	2
Nickel	20	7	220
Phosphorus (elemental)	0.10	-	-
Silver	0.45	0.3	2
Zinc	20	10	260

^a All concentrations are in micrograms per liter (ug/l) except fecal coliforms which are expressed as a number per 100 milliliters.

Quality guideline for un-ionized ammonia is higher at lower temperatures, lower pH and higher ionic strength. The criterion is to keep unionized levels below 20 ug/l.

Source of information: U.S. EPA, 1976; Klapow and Lewis, 1979; and Brown and Caldwell, September 1982.

TABLE 6.1-2

PROJECTED EFFLUENT QUALITY FOR OCEAN DISCHARGE
AND APPROXIMATE MARINE WATER QUALITY

<u>Constituent</u>	<u>Effluent</u>	<u>Receiving Water</u>
Five-day biochemical oxygen demand (BOD), mg/l ^a	30	-
Total suspended solids, mg/l ^a	30	-
Fecal coliform, MPN/100 ml ^b	200	-
Total Kjeldahl nitrogen, mg/l ^a	25	-
Ammonia nitrogen, mg/l, as nitrogen	15	-
Floating solids	none	-
pH	Between 6 and 9	-
Temperature, degrees C	Between 6 and 24	-
Arsenic, ug/l ^c	2	3.0
Cadmium, ug/l	1	0.1
Chromium, ug/l	25	0.05
Copper, ug/l	-	2.0
Cyanide, ug/l	125	-
Lead, ug/l	30	NA ^d
Mercury, ug/l	0.03	0.05
Nickel, ug/l	10	2.0
Silver, ug/l	1.0	NA
Pesticides, ug/l	0.010	-
Zinc, ug/l	50	NA

^a Monthly average, milligrams per liter.

^b Monthly average, MPN/100 ml equals most probable number per 100 ml.

^c ug/l equals micrograms per liter or parts per billion.

^d Not Available

Source: Brown and Caldwell, September 1982.

wastewaters can vary widely depending upon the characteristics of untreated wastewater and treatment efficiency.

In addition, sewage sludge and, to a lesser degree, effluent can contain toxic metals and pesticides as well as viruses. Pathogens settled in sediments may be resuspended by physical disturbances such as dredging (Taylor, 1973). Ellender et al. (1980) reported that viruses can remain infectious in sediments and returned to the water column through physical or chemical action.

The following factors should be considered in evaluating a wetland for receiving treated wastewater:

- . Availability of other reasonable wastewater disposal alternatives;
- . Use(s) of adjacent groundwater and downstream waters (if any);
- . Impacts of municipal wastewater on vegetation and animal life;
- . Use(s) of wetland area: wastewater disposal or wastewater treatment and disposal, in addition to other uses;
- . Treatment mechanisms: biochemical uptake-harvesting, adsorption onto surfaces, gas release (anaerobic for nitrogen), ion exchange, coagulation;
- . Types of vegetation within the wetland that can affect wetland treatment efficiency;
- . Temperatures within Region IV are favorable for treatment, although seasonal differences are notable;
- . Storage of wastewater prior to discharging wastewater to a wetland can provide wastewater management flexibility;
- . The benefits of disinfection as compared to cost and other adverse effects; and
- . The presence of endangered species or commercially-valuable species which could be adversely affected.

No information about achievable treatment efficiency, flow rates, or other engineering parameters is available for saltwater-wetland systems in EPA Region IV. Some information for freshwater wetland-wastewater systems is reported in another EPA document (U.S. EPA, February 1983). For freshwater wetlands, flows of wastewater per area of affected freshwater wetland vary in Region IV from 0.3 to 13 centimeters per week.

Effects of Wastewater on Saltwater Wetlands

If a wetland is to be used to receive treated wastewater, then adverse impacts need to be controlled and natural processes occurring within the wetland must be disturbed as little as possible. Potential impacts and mitigation measures are reviewed by Nelson and Weller (1984). Wastewater loading rates, water depths, detention time and flow patterns are factors that can disrupt a wetland system if not controlled.

Some of the impacts of discharging wastewater to wetlands have been observed, while other impacts are speculative. The major types of impacts that can occur are listed in Table 6.1-3; whether some or all of these impacts do occur depends upon the design, installation, and maintenance of the wetland wastewater system. Effects also may vary substantially with tidal cycles and on a daily and seasonal basis. No long-term investigations of these impacts on saltwater wetlands have, however, been conducted. In general terms, the adverse effects of particular wastewater constituents are listed in Table 6.1-4.

As discussed in Chapter 5.0 of this report, both positive and negative impacts on natural ecosystems can result from the addition of wastewater to saltwater wetlands. Wastewater free of harmful industrial

TABLE 6.1-3
POTENTIAL IMPACTS OF WASTEWATER
ON WETLAND ECOSYSTEMS

DOCUMENTED EFFECTS:

- Increased plant productivity
- Altered species composition within the plant community
- Altered animal populations as a result of food and habitat changes
- Altered soil/substrate
- Altered elemental content of plants (including nutrients)

SPECULATIVE EFFECTS:

- Changes in detrital cycling
- Accumulation or transfer of metals, chlorinated by-products and perhaps other undesirable elements or compounds within the food chain
- Transmittal of viral or bacterial diseases at various levels of the food chain
- Changes in salinity levels and ionic strength
- Dampening of tidal effects on wetland water levels
- Conservation of wetland areas
- Potential cost savings if a saltwater wetland can be utilized

Based largely on Table 17 in Hammer and Kadlec, 1983.

NOTE: The effects which have been documented are based on observations in freshwater wetlands.

TABLE 6.1-4
POTENTIAL ADVERSE EFFECTS OF CERTAIN
WASTEWATER CONSTITUENTS

<u>Constituent</u>	<u>Adverse Effect</u>
Toxic Substances:	
1) Heavy metals (particularly mercury, copper and zinc)	Inhibited reproduction or development of aquatic life forms Decreased brain or liver activity of aquatic life forms Bioaccumulation of certain metals, such as mercury, in higher levels of food chain
2) Free Ammonia Nitrogen (only at pH exceeding 8)	Gill and liver function and effects of blood on fish
3) Chlorine Residual	Fish, shellfish and phytoplankton inhibition
4) Chlorinated Hydrocarbons	Inhibition of respiration/photosynthesis Carcinogens to mice and rats Considered to be carcinogenic to humans Bioaccumulation in fish leading to growth inhibitions Acute toxicity to fish and invertebrates
5) Elemental Phosphorus (normally oxidized rapidly to phosphate)	Fish and shellfish toxicity Bioaccumulation
Nutrients	Possible eutrophication due to excess productivity
Solids	Reduced light penetration Altered bottom habitat
Bacteria and Viruses	Diseases transmitted to humans (typhoid, hepatitis and others) Accumulation in shellfish
Synthetic Organic Compounds	Potential carcinogens
Detergents	Decreased surface tension Sensitive to air-water interchanges

Sources: U.S. EPA, 1976; Klapow and Lewis, 1979.

chemicals can increase biological productivity in a wetland, if forms of nutrients which are in limited supply in a wetland are available in wastewater treatment plant effluent. Improvements in wildlife habitat have been noted in at least two artificial wetland wastewater systems (Hammer and Kadlec, 1983). On the other hand, water depths greater than 0.7 meter significantly inhibit the growth of rooted plants which inhabit the intertidal zone, particularly Spartina alterniflora. The dampening effect of wastewater on water depth fluctuations resulting from tides also is discussed in Chapter 5.0.

If dikes, berms, permanent trenches or other modifications are made to a saltwater wetland, then water circulation would be disrupted. Any changes to the extent of salinity intrusion inland due to tidal waters could affect the numbers and types of vegetation and subsequently the wildlife that exist in a wetland area. Changes in water velocities can also alter the local ecological community, because different life forms can prefer different environmental conditions.

If a wetland is being utilized for wastewater management, less incentive may arise in the future to fill that wetland for residential or commercial development. The use of a wetland for wastewater management could therefore help to preserve that wetland. Other benefits are the additional treatment of wastewater that can occur in a wetland and the costs savings that could be realized by a potential discharger.

6.1.1 Planning and Preliminary Design

Several factors must be considered in order to minimize the adverse impact of wastewater and to optimize the pollutant removal capability of a wetland. The factors discussed in this section include wastewater loading rates, wastewater detention time and flow patterns, water depths, enhancement of pollutant removal abilities within a wetland, and chlorination.

6.1.1.1 Wastewater Loading Rates

Hydraulic, organic and nutrient loading rates merit consideration in this study. Depending upon the following factors, one of these loading rates can govern the design of a treatment facility: desired water depths, treatment required, detention time of water within the wetland, vegetation, percolation through soil, temperature, and precipitation. The loading rate which allows the smallest application of water, organic material or nutrients to a wetland will govern design and subsequent activities.

No studies, however, have been found that document impacts resulting from variations in hydraulic, organic or nutrient loading rates for wastewater discharged to saltwater wetlands. Furthermore, results of studies in freshwater wetlands vary with the type of wetland studied, water movement patterns within the wetland (e.g. significance of soil infiltration compared to water flowing through a wetland), climate, season, and differences in measurement and reporting techniques. In a study at Hay River in Canada, wastewater discharge resulted in a signifi-

cant reduction in the diversity of some wetland species. However, in another study at Great Meadow National Wildlife Refuge in Massachusetts, no stress was noticed, even though the concentration of pollutants discharged was similar to the concentration discharged in Canada (Chan et al., 1982).

The hydraulic loading rates of wastewater discharged to freshwater wetlands studied in Region IV vary greatly, as shown below (U.S. EPA, February 1983).

<u>Location</u>	<u>Pre-Treatment</u>	<u>Hydraulic loading, ha/m³-day(acres/mgd)</u>
Whitney Park, FL	Secondary	0.026 (243)
Wildwood, FL	Primary	0.214 (1,997)
Reedy Creek, FL	Secondary	0.0054 (50)
Gainesville, FL	Package plant	0.0168 (157)
Jacksonville, FL	Secondary	0.094 (880)

ha/m³-day: hectare per cubit meter per day

mgd: million gallons (of wastewater) per day

Nutrient loading rates only for short time periods (less than one year) have been reported for wastewater being discharged to natural freshwater wetlands in Region IV. For artificial freshwater hyacinth wastewater systems in warm climates, the loading rates for five-day biochemical oxygen demand (BOD) and for total Kjeldahl nitrogen (TKN) are less than or equal to 45 and 13 pounds per acre per day, respectively (50 and 15 kilograms per hectare per day). These reported loading rates are for systems receiving secondary-treated wastewater (U.S. EPA, February

1983). Allowable organic loading rates are dependent largely upon the detention time of wastewater in wetland waters with aerobic conditions. Nutrient loading rates can differ depending upon the rate of soil and vegetative uptake of nutrients and, for phosphorus, the extent to which wastewater percolates through the soil.

From an engineering standpoint, a range of loadings supplemented by site-specific information is needed as a guideline for planning wetland wastewater systems and in estimating allowable loadings.

6.1.1.2 Wastewater Detention Time and Flow Patterns

Detention time in wetland wastewater systems is the period of time wastewater resides within a wetland. Some important wastewater treatment mechanisms require time, such as removal of suspended solids, oxidation of organic material (BOD removal) and oxidation of ammonia to nitrate. If optimizing the pollutant removal ability of a wetland is not a management objective, then detention time becomes much less important as a design factor. Detention time depends upon the volume of water within a wetland, flow patterns within a wetland, and the flow of water into and out of a wetland. Detention time in a saltwater wetland will vary quite radically within a tidal cycle, from season to season or as a result of storms.

Detention time is estimated by dividing the volume of water within a wetland by the flow through the wetland, where flow includes groundwater infiltration and evapotranspiration as well as surface water outflow.

This method of estimating detention time is valid for ideal systems, in which water flows either as a slug or is completely mixed through the wetland. However, water flowing within a natural wetland often can follow shorter-than-average flow paths. Use of a tracer dye is one method to estimate detention time in such non-ideal systems.

6.1.1.3 Wetland Water Depths

Water depth is an important factor in the management of wastewater within a wetland. Excessive water depths can result in a lack of oxygen in bottom waters that may adversely impact biological communities. For artificial freshwater wetland systems, the reported range of water depths is 0.5 to 3 feet (0.2 to 0.9 meter; Crites, in U.S. EPA, September 1979). There are no reasons why water depths for natural systems would differ significantly from water depths for artificial systems. Greater water depths can increase the removal of suspended solids, but depths greater than about 4 feet can result in the depletion of dissolved oxygen in bottom waters and sediments (U.S. EPA, May 1975).

Oxygen does not dissolve as well in seawater at equilibrium (6.7 mg/l saturation at 25°C) as it does in freshwater (8.4 mg/l saturation at 25°C; APHA et al., 1975). Hence, water depths in saltwater wetlands of greater than 4 feet could result in depletion of dissolved oxygen in bottom waters and sediments if the waters are not well agitated.

6.1.1.4 Pollutant Removal Mechanisms

Wastewater constituents can flow out of a wetland via surface water or groundwater, volatilize into the atmosphere, remain in marsh biota and/or sediments, or be chemically or physically converted during residence in the wetland.

Of the various physical and chemical pollutant removal mechanisms shown in Table 6.1-5, decomposition, adsorption and sedimentation are often the most important. If significant groundwater recharge takes place, filtration can also become important. Adsorption and decomposition are important, particularly in warm climates, because of the high biological productivity and large amounts of suspended material found in saltwater wetlands. Sedimentation can be important if water velocities are low. As solids settle, particle sizes often increase in the saltwater column due largely to the high ionic strength of brackish waters (Edzwald et al., 1972).

Aquatic plants can enhance pollutant removal, although plants that float or are submerged without roots and thus can extract nutrients directly from the water column are more common in freshwater wetlands than saltwater wetlands. Harvesting of aquatic plants has been tested in some artificial wetland systems as a method to enhance plant production thereby enhancing nutrient removal. All aquatic plants also provide sites for bacteria that biochemically degrade organic matter to residue.

TABLE 6.1-5 PHYSICAL AND CHEMICAL POLLUTANT REMOVAL MECHANISMS IN WETLAND AND AQUATIC SYSTEMS

Mechanism	Pollutant affected							Description
	Settleable solids	Colloidal solids	Organic compounds	Petroleum hydrocarbons	Nitrogen	Phosphorus	Heavy metals	
Physical								
Evaporation			X	X			X ^a	Volatilization and aerosol formation
Sedimentation	X	X		X	X		X ^a	Gravitational settling of particles and adsorbed pollutants
Emulsification		X	X	X			X ^a	Suspension of chemicals that are sparingly soluble in water within an aqueous environment
Adsorption		X	X	X			X	Electrostatic attraction, Van der Waals force
Filtration	X	X						Mechanical filtration of particles through substrate, roots or animal systems
Chemical								
Chelation						X	X	Formation of metal complexes through ligands
Precipitation				X		X	X	Formation of or coprecipitation of insoluble compounds
Decomposition			X	X	X	X	X	Alteration of less stable compounds by oxidation, reduction, hydrolysis or photochemical reaction
Chemical adsorption			X	X	X	X	X	Covalent bonding, hydrogen bond formation, hydrophobic interaction

a. Significant only for mercury.

b. Not significant for manganese and mercury.

Reference: Chan, et al. 1982

Decomposition is particularly affected by water temperature. Average temperatures within Region IV states are typically high enough to allow for decomposition. The climate in the southeastern United States also promotes long vegetative growth periods, which can be advantageous for enhancing wastewater renovation processes. Because plants and other life forms are dormant during winter months, wastewater assimilation by plants should be supplemented by other treatment methods or storage capacity if nutrient removal during winter months is an important objective.

Removal of pollutants by physical processes, such as sedimentation or soil adsorption, is also affected by seasonal changes but to a lesser extent than is biological conversion of pollutants. Therefore, wetland wastewater systems that rely on physical processes can more easily be designed for year-round operation than can systems relying on biological processes.

Significant questions remain regarding pollutant removal efficiencies as a function of time, the effects of ionic strength, temperature and biota, and the long-term ability of any wetland to remove wastewater constituents. Saltwater wetlands have unique water circulation characteristics due to their unique topographic nature. With large amounts of flushing of saltwater wetlands during a tidal cycle, the ability of a wetland to renovate wastewater can be limited because of limited water retention times. Treatment kinetics vary depending upon the concentration of constituents, temperature, ionic strength and biochemical activity. One wetland may be better suited to utilizing a certain

wastewater constituent (e.g. nitrogen) than another wetland. Long-term renovation is a question which has been addressed only in a few projects involving freshwater wetlands. Constituents which settle, adsorb or filter out of solution are usually stored within the wetland. Eventually enough material could be stored so as to alter the wetland system. No significant adverse effects on wetland ecology have been observed in the few freshwater wetland wastewater systems that have received secondary-treated wastewater for 3 to 5 years or longer.

Site-specific data that could be collected to evaluate the potential of a wetland to be used for wastewater management are shown in Table 6.1-6.

6.1.1.5 The Need for Chlorination

Traditionally, wastewater is disinfected prior to being discharged in order to reduce the possibility of public health problems. However, wetlands have been shown to be able to assimilate bacteria and other microorganisms. Furthermore, some concern exists about the effects of chloramines (a by-product of chlorine and ammonia from wastewater) and chlorine remaining in the wastewater when discharged. In this regard, the available options are: use of chlorine, use of another disinfectant such as ozone or ultra-violet light, use of chlorine followed by dechlorination (via pond retention or sulfur dioxide), or no disinfection. The option of no disinfection is less costly and avoids safety concerns with chlorine use but may result in adverse public health impacts depending upon: (1) individual wetland characteristics and accessi-

TABLE 6.1-6

COLLECTION OF SITE-SPECIFIC DATA FOR EVALUATION
OF A WETLAND FOR WASTEWATER TREATMENT

Water Budget

- Annual precipitation, cloud cover and radiation data acquisition
- Streamflow data
- Water level records for wetland and adjacent water bodies
- Subsurface flow patterns
- Surface elevation survey
- Overland flow patterns
- Tidal effects on flows and water levels

Seasonal Water Quality

- Nitrogen, phosphorus, chloride
- Coliforms, BOD, suspended solids, TDS, etc
- pH, temperature, conductivity

Soil Processes

- Type and depth of peat, detritus
- Ion exchange capacity of peat
- Permeability (hydraulic conductivity)

Flora and Fauna

- Algae inventory
- Plants - cover map, identify endangered species, nutrient status
- Invertebrate inventory

Use Patterns

- Vertebrates (e.g. reptiles, mammals, and birds)
- Human

Source of selected information: Hammer and Kadlec, 1983

bility; (2) variations in those characteristics with time; and (3) constraints of existing state water quality classifications, such as for shellfish waters.

Dechlorination following chlorine disinfection can remedy potential problems with chlorinated by-products while still allowing disinfection to take place. Dechlorination can be accomplished by retaining chlorinated wastewater in a shallow pond during daylight hours prior to release to the wetland or by utilizing sulfur dioxide. Pond retention requires much less operation and maintenance, however land requirements are much greater than for addition of sulfur dioxide.

6.1.1.6 Mathematical Modeling of a Wetland as a Planning Tool

To be utilized as a planning tool, a model would need to simulate wetland hydrology and perhaps water quality in such a way that discharge permit requirements could be established. Such a hydrologic or water quality model would need to be able to predict water circulation patterns and water quality processes, by solving mathematical equations simultaneously for numerous sections of the wetland.

Models have been developed which simulate water budgets for a particular wetland area (as reported in U.S. EPA, February 1983). Ecological processes have also been simulated. One problem is that separate models are needed for each wetland which makes the evaluation of hydrology and water quality for a number of wetland areas very time consuming and costly. A second problem is that a large amount of field data is needed before a model can be utilized.

As reported by U.S. EPA (February 1983), different states in EPA-Region IV utilize different types of models to assess discharge permit requirements. Most models utilized by state agencies are based on models utilized for streams and rivers; the problem with these models is that flow within a wetland is lateral as well as longitudinal.

6.1.2 Design of Municipal Systems

Design considerations incorporate a finer level of detail than what is necessary for planning. The design items addressed in this section are wastewater circulation patterns, costs, energy and chemical usage, and additional considerations. Design considerations are also provided.

6.1.2.1 Wastewater Circulation Patterns

While many points of discharge can be considered in a wetlands alternative, wastewater is typically released at the edge of a wetland and as close to the wastewater treatment plant as possible. The decision of where to locate a discharge is usually based on cost considerations.

Discharge sites can be located at the edge of a wetland, or within the interior of a wetland away from homes or valuable wetland habitat. Costs and the ease of obtaining pipeline right-of-way are important factors that could affect the feasibility of a discharge within the interior of a wetland. A single pipe or channel, multiple pipes, multiple ports from one pipe, or sprayers can be utilized to release wastewater to a wetland. A decision concerning each discharge location should be made independently based on that wetland's flow paths, vegetation types, vegetation densities, erosion potential and pollutant removal potential.

Table 6.1-7 presents the advantages and disadvantages of four types of discharge configurations in terms of costs, impacts on the environment due to pipeline (or channel) placement, and maintenance. Releasing wastewater in a way that significantly alters natural flow patterns within a wetland is not recommended. Better matching of discharge rates to natural flow patterns can be obtained by using storage ponds at or adjacent to the wastewater treatment plant to regulate flows of wastewater entering a wetland.

Artificial control of water circulation has been instituted only with artificial wetlands. Artificial flooding and control of water depths would be much more difficult to implement effectively in saltwater wetlands than in freshwater wetlands, because saltwater wetlands are affected by tidal influences. Outlet flows from a saltwater wetland can not be artificially controlled without also affecting water salinity and hence affecting the entire wetland ecosystem.

6.1.2.2 Costs

In general, the more costly activities are the ones that would affect wetland ecosystems most significantly, such as harvesting vegetation or using physical structures to control flow paths within a wetland.

The use of wetlands for wastewater management can be cost effective. Tchobanoglous et al. (U.S. EPA, September 1979), Sutherland (in U.S. EPA, 1979) and others have demonstrated that the use of freshwater wetlands for wastewater treatment beyond the secondary level can be significantly less costly than conventional treatment processes.

Table 6.1-7 Effluent Application Configurations.¹

Effluent Applications Configurations	Advantages	Disadvantages	Comments
Point Discharge at edge of wetland, gravity flow	- Low Cost - Low O&M requirements - Low energy use - Can be installed with minimal impacts to a natural wetland	- Often poor or unknown distribution of wastewater - Erosion and channelization may occur if wastewater velocity is high - Solids may accumulate near discharge if wastewater velocity is low	- Distribution may be improved by selection of discharge point to take advantage of natural flow paths, increasing the number of discharge points, or enhancing mixing within the wetland by mechanical or physical devices - Erosion control techniques are available.
Channel discharge at edge of wetland, gravity flow	- Low O&M requirements - Installation impacts limited to edge of wetland - May provide some dechlorination within channel (cascade affect)	- Often poor or unknown distribution of wastewater - Erosion or channelization may occur if wastewater velocity is high - Solids may accumulate near discharge if wastewater velocity is low.	- Concrete or grass-lined channel may be used - Erosion control techniques are available
Distribution within wetland, gravity flow	- More uniform distribution than point or channel discharge - Relatively low O&M requirements (no moving parts)	- Installation impacts to natural wetlands - Installation costs	- Distribution may be accomplished by pipe outfalls at a variety of points within wetland, or by perforated or gated pipes - Pipes can be installed on the surface, buried or elevated - Surface pipes will have lesser installation impacts and costs but will have greater O&M requirements
Distribution within wetland, spray flow	- More uniform distribution than point or channel discharge - May provide some dechlorination - Low erosion potential via spraying	- Aerosols may cause public health impacts - Energy required - Nozzles may clog unless pre-treatment includes fine screening - O&M requirements higher than for other alternatives - Installation impacts to natural wetlands - Installation costs	- Piping may be laid on the surface, buried or elevated - Surface piping will have lesser installation impacts and costs but will have greater O&M requirements

1. U.S. EPA, Assessment of current information on overland flow treatment of municipal wastewater, May 1980.

To install a wastewater outfall in a wetland area, four examples of costs have been estimated for the following wastewater disposal options:

- a. A channel, 500 feet in length, to the edge of a wetland (grass-lined with gates; no supplemental pumping);
- b. A buried pipe through 500 feet of dry soil. Assume that no rock and no significant soil freezing are encountered and that no significant pumping of wastewater is required.
- c. Same as (b), above, except that the buried pipe traverses 500 feet of soil where the water table is at the soil surface (wet soil).
- d. The same as option (b) except that two 500-foot pipes (within a wetland) extend in the wetland in different directions. Sprayers are located at the end of each of these two buried pipes.

Costs have not been included for land acquisition or wastewater storage ponds. Operation, maintenance and repair costs for pipelines and sprayers have also not been included, but such costs would be low for 500 to 1,000 feet of pipe over a 30 to 40-year service life. The service life of a pipeline may be shorter in a saltwater wetland than in a freshwater wetland due to saline soil conditions.

The following assumptions have been used in this cost analysis:

- Costs are in second quarter, 1983 dollars for Atlanta, GA (Engineering News Record construction cost index = 4003);
- Excavating, dewatering, and backfilling costs are included as well as costs for engineering, construction supervision and contingencies;
- Channel costs are based on a 3.5 foot channel depth and a 1:2 channel side slope;
- Pipelines are assumed to be buried approximately 1 foot below the soil surface;
- For dry soil excavation, a crawler-mounted backhoe can be utilized. Costs can vary depending upon the type of soil being

excavated, but a typical cost of \$4 per cubic yard was utilized; and

- For wet soil excavation, a dragline was assumed to be utilized for excavation. Typical costs are \$5 per cubic yard. No additional costs were included to account for intermittent installation. Trench dewatering, if needed, would only increase the total capital costs by approximately \$500.

Table 6.1-8, which gives results of the cost estimates, shows that, for 1 million gallons per day (MGD) capacity, a channel is the least costly method of installation, followed by buried pipeline. Costs for excavation and pipeline installation in wet soils are basically the same as costs in dry soils. The use of sprayers to distribute wastewater once it reaches the termination of the pipeline adds approximately \$6,000 of costs per sprayer for capacities of 1 to 5 MGD of wastewater. The use of wooden supports more than doubles the cost of transporting wastewater to a wetland area, based on costs encountered at Houghton Lake, MI (updated to 1983 cost indices). Capital costs for providing chlorination far exceed costs for transporting wastewater a reasonable distance away from human populations, even without considering the significant operating costs for chlorination.

6.1.2.3 Energy and Chemical Usage

Operation of any wetland-wastewater system could require energy for the following uses: wastewater pumping, wastewater spraying, utility vehicle(s) for monitoring and maintenance, and harvesting of vegetation. All of these energy-using operations may be avoidable except perhaps the utility vehicle(s). Pumping requirements would be relatively small, because wetland elevations are lower than nearby upland elevations.

TABLE 6.1-8
SUMMARY OF EXAMPLE
WASTEWATER DISPOSAL CAPITAL COSTS

		<u>Capital Cost, \$</u>	
		(ENR ¹ = 4003)	
A)	Man-made channel 500 feet in length:		
1)	Wide-bottom, grass-lined ditch (for 1 mgd capacity)	8,000	
2)	Wide-bottom, grass-lined ditch (for 5 mgd capacity)	30,000	
B)	Piping - single pipe through 500 feet of dry soil		
1)	12" diameter (for 1 mgd capacity)	11,000	
2)	24" diameter (for 5 mgd capacity)	14,000	
C)	Piping - single pipe through 500 feet of wet soil (costs do not include artificial dewatering; installation may need to take place during periods before and after low water slack.)		
1)	12" diameter (for 1 mgd capacity)	11,100	27,000 ⁽²⁾
2)	24" diameter (for 5 mgd capacity)	14,000	29,000 ⁽²⁾
D)	Piping - dual plastic pipes each extending 500 feet in wet soil with sprayers to distribute wastewater		
1)	12" diameter (for 1 mgd capacity)	35,000	66,000 ⁽²⁾
2)	24" diameter (for 5 mgd capacity)	40,000	72,000 ⁽²⁾
E)	Chlorination		
1)	For 1 mgd capacity	105,000	
2)	For 5 mgd capacity	221,000	

(1) ENR refers to the Engineering News-Record Construction Cost Index.

(2) If pipeline is supported on or above the soil surface by wooden supports rather than buried beneath the soil surface.

Sources of information: Robert Snow Means Co., 1983; U.S. EPA, February 1980; and Hammer and Kadlec, 1983.

Harvesting of vegetation within a natural, saltwater wetland is not known to have been attempted on a long-term basis; concerns exist about adverse environmental impacts as well as energy and labor requirements.

The amount of fuel utilized by a utility vehicle would depend upon the size of the wetland and the extent of monitoring and maintenance activities.

Use of a wetland for wastewater management is a natural process, while conventional wastewater treatment processes often require aeration, mixing chemical addition and perhaps supplemental heat to operate effectively. A conventional wastewater treatment process is, therefore, more energy intensive than is treatment provided in a natural wetland.

6.1.2.4 Design Considerations

Many important planning concerns must also be considered in the design and installation of a wastewater project involving wetland areas. These design considerations include:

- . Determination as to whether supplemental wastewater treatment is to be included as a wetland design objective;
- . Estimates of wastewater detention time, water circulation patterns, water depths and (if needed) treatment kinetics for a wetland area;
- . Weekly and seasonal variations on biological activity (e.g. flooding, drought, winter slowdown);
- . Need for chlorination or another form of wastewater disinfection, followed by a cost assessment, if a need exists;
- . Need for supplemental wastewater storage volume, followed by a development of sizes and costs for storage facilities, if a need exists;

- Precise locations(s) of wastewater outfall;
- Specific method of wastewater discharge (end of pipe, diffuser pipe, sprayers and choice of materials);
- Method of placing pipeline;
- Operation and maintenance activities anticipated after installation;
- Contingency plan in case of unusual problems or upsets;
- Overall costs vs. benefits of wastewater discharge system;
- Need for pilot-scale facility;
- Plan for effective system installation; and
- Plan for phasing in discharge activities following installation.

In order to effectively address the above stated concerns, persons familiar with the local wetland hydrology and ecology should be consulted as the wastewater storage and pipeline facilities are designed and installed.

Additional design concerns that may need to be considered include the following four points. First, a quantitative mass balance for each pollutant to be treated within the wetland may need to be considered. By knowing the quantities entering a wetland and estimating treatment efficiencies, quantities leaving a wetland can be estimated and later checked when the system is in operation. The mass balance estimates may vary because of seasonal variations. Mass balance estimates may also vary over a longer time frame (e.g. 10 to 15 years) if pollutants accumulate within a wetland and are eventually released.

Secondly, variability among equipment manufacturers may need to be recognized. Certain manufacturers may provide types of equipment that are more suitable for wetland alternatives than other manufacturers (e.g. sprayers, diffuser pipes). Less frequent maintenance is preferred for facilities located within a relatively inaccessible wetland even if costs for less frequent maintenance are somewhat higher. Plastic or aluminum pipe should be suitable for the saline, somewhat corrosive environment of a saltwater wetland.

Third, specifications for installation may be developed which include requirements to minimize the impacts of construction on wetlands. Examples of possible specifications are the following:

- . Installation could be restricted to a certain season;
- . Excavated soil can be replaced to original contours following installation; and
- . Specific equipment requirements can be dictated.

Fourth, a contingency plan should be considered in case of extreme weather conditions, treatment plant failures, or sudden changes in wastewater characteristics. As mentioned earlier in this section, wastewater can be stored or an alternative method of emergency wastewater disposal can be utilized. Control of extreme water levels or excessive erosion is nearly impossible in a saltwater wetland, because upstream flows are often very large, and outlets to coastal waters occupy a large geographic area.

The following design guide and checklist for aquatic systems (Table 6.1-9) adopted from Stowell et al. (1980) summarizes important design considerations for wetland alternatives.

6.1.3 Installation and Operation-Maintenance-Repair

Installation is usually conducted so as to minimize costs to the contractor. Hence, any environmental requirements during installation need to be included in the written contract specifications supplied to the bidding contractors. Examples are given in Section 6.1.2.4. Various methods have been utilized in freshwater wetlands on an experimental basis to minimize disturbances due to installation. Unnecessary soil compaction can be avoided. Pipelines can be suspended on a trestle-like structure above the wetland. Installation can be conducted during periods of the year when the local wildlife are not particularly vulnerable (e.g. avoiding installation during annual breeding periods). When working in a wetland, construction inspectors could be employed who are aware of the potential environmental impacts of various activities as well as the problems associated with activities performed in saturated soils. Otherwise, a failure of at least a portion of the wetland system to survive could occur as a result of installation activities.

The most important design decision, from the installer's perspective, is whether the wastewater is to be released from a channel, or piped above or below ground. Channels require more maintenance than pipelines, but pipelines above the ground surface are susceptible to storms, cold temperatures, animals and other external effects. Pipelines

TABLE 6.1-9

DESIGN GUIDE AND CHECKLIST FOR WETLAND-WASTEWATER SYSTEMS

Preliminary Investigation

1. Survey sites suitable for a wetland-wastewater system in terms of current uses, water quality standards and discharge requirements.
2. Review and summarize climatic and hydrologic factors: temperature, precipitation, and wind; flow paths and water levels during flood and ebb tide; vulnerability to coastal storms.
3. Survey local flora: growth season, vegetative structure through winter, and potential to affect aquatic environments to evaluate effects of wastewater on vegetation (including ability of vegetation to uptake nutrients).
4. Review discharge requirements: are seasonal requirements possible if justified?
5. Review literature with emphasis on type of project being envisioned, contaminant removal mechanisms, and treatment performance and reliability.
6. Formulate preliminary aquatic system design, including use of conventional treatment processes and use of disinfection.
7. Analyze cost effectiveness of alternative wastewater treatment processes: go or no-go aquatic system design.

Aquatic System Design

1. Itemize expected flows, influent concentrations, and discharge requirements.
2. Identify contaminant removal mechanism(s) and environment(s). (Complete this analysis for each contaminant to be removed if treatment of wastewater within a wetland is important or if particular industrial wastes raise concerns.)
 - a. Removal mechanism(s).
 1. Identify removal mechanism(s) operative on contaminant of concern.
 2. Summarize kinetics of removal mechanism(s) and factors affecting the kinetics: contaminant concentration, temperature, pH, etc.
 - b. Aquatic environment(s) required for removal mechanism(s) to be operative.
 1. List requirements for aquatic environment(s).
 2. List factors affecting these requirements: climatic factors, organic loading rate, plant species, chemical and equipment input, etc.
3. Determine precise location(s) of wastewater discharge and type of distribution system.
 - a. What components necessary to the aquatic environment will it provide?
 - b. Seasonality in the local environment?

TABLE 6.1-9
(continued)
DESIGN GUIDE AND CHECKLIST FOR WETLAND-WASTEWATER SYSTEMS

- c. Local diseases and predators: seasonal or year round?
 - d. Nuisance potential?
 - e. Chemical and equipment input.
 - 1. What components necessary to the aquatic environment will it provide?
 - 2. Continuous, seasonal, or emergency use?
 - f. Management options to maintain aquatic environment (e.g. harvesting).
 - g. Rate of contaminant removal (if treatment of wastewater within the wetland is important) surface area requirements on a seasonal basis.
4. Design aquatic system.
- a. Are the discharge requirements met?
 - b. What measures can be taken to increase the reliability of the system?
 - c. Complete quantitative mass balance (in terms of removal mechanism kinetics) for each contaminant for the seasons of the year, if treatment of wastewater within the wetland is important.
 - d. Management.
 - 1. To maintain the system.
 - 2. Courses of action in cases of system upset: contingency plan.
5. Make final check on cost effectiveness of aquatic system.
6. Possibly design and operate pilot scale facility. (This step is necessary if contaminant removal mechanism rates and factors affecting these rates are to be quantified. If the pilot does not function as anticipated, aquatic system design steps 2 through 6 will have to be modified as necessary. Failure of the pilot facility could result in the wetland disposal alternative being dropped from consideration.)
7. Design and construct full-scale aquatic system. Include any specifications which are considered important in limiting the freedom of the installer to concentrate solely on minimizing installation costs.

Adapted from Stowell et al., 1980

below ground are susceptible to differential soil movement in some wetland areas. For wetlands with firm substrates a "push-ditch" method for burying pipeline causes temporary turbidity from the dredging operation but once the pipe is installed and backfilled, the impacts subside (Conner et al., 1976). Environmental impacts from installation are less significant for above-ground pipelines. All three methods of transporting water have been utilized in wetland systems.

Proper operation, maintenance and repair are vital, because failure of a wetland to assimilate wastewater could result in adverse effects on the natural, saltwater wetland. Good planning, design and installation can be negated by improper operation, maintenance or repair.

Important operation, maintenance and repair can include: (1) controlling the quantity and quality of released wastewater; (2) altering water flow paths within a wetland, if appropriate; and (3) controlling the quantities of living vascular plants; and (4) pipeline maintenance. The third and fourth types of activity are more costly to conduct than the first two.

Flexibility should be incorporated into the design and construction of a project. If wastewater storage facilities and/or alternative wastewater disposal techniques have been designed and installed, operation can be more flexible than if these options for controlling wastewater flows are not available. Water flow paths can be altered if alternative locations for releasing wastewater to a wetland are available, if dikes are in place, or if sediments within a wetland are

allowed to be dredged. Aquatic plants can be controlled by physical harvesting or the use of herbicides or biological controls; vegetation can be increased by seeding or planting portions of a wetland.

Methods for promoting proper operation, maintenance and repair are available:

- Operating requirements of the wetland wastewater system can be combined with treatment plant operations. A combined operation-maintenance-repair manual for the treatment plant and the wetland can be developed. In addition, the same personnel can be responsible for both the operation of the treatment plant and the wetland.
- Manufacturers can provide recommended periodic maintenance intervals for equipment (e.g. for sprayers).
- Periodic inspection can be conducted in conjunction with a monitoring program.

6.1.4 Monitoring

Effluent and wetland monitoring can be required as part of a municipality's NPDES (National Pollutant Discharge Elimination System) permit. Monitoring at various stages within the wastewater treatment plant could also be required. The municipality could be asked, possibly with the help of a wetland specialist, to propose an ongoing monitoring program as part of its NPDES permit application. Once the contents of the monitoring program are agreed upon and implemented, periodic monitoring results could be presented to the responsible state agency for review. Modifications to the program may be developed as results are used to help assess the impact of the wastewater on wetland use and function.

Possible elements of a monitoring program are the following:

- a. What to monitor: water levels, pH, dissolved oxygen, specific conductance, suspended solids, five-day BOD, coliform bacteria, alkalinity, nutrient levels, biological indicators, vegetation.
- b. Where to monitor:
 - Upstream of the wastewater discharge within the wetland, the wastewater itself, downstream of the discharge within the wetland (perhaps at a number of locations), and downstream of the wetland itself as appropriate (e.g. estuarine waters).
 - Surface water, sediment, groundwater, various locations within wastewater treatment plant.
- c. When and how often to monitor:
 - Daily, weekly, monthly, seasonal
 - Before, during and/or after a rainfall event
 - Low-flow, average-flow and/or high-flow period
 - Ebb tide, slack, and flood tide
 - Different times of day (important to biochemical reactions)
- d. How to monitor: procedures with reasonable logistics and monitoring effectiveness may be needed for each wetland wastewater system.
- e. Equipment, field procedures, laboratory procedures and reporting procedures.

These monitoring elements are listed only to show the broad range of monitoring possibilities. Specific decisions about what, where, when, how often and how to monitor will differ for each wetland wastewater system as agreed to by the municipality and the responsible regulatory agency. The extent of monitoring that is considered worthwhile will not be well understood until wetland characteristics have been defined through field efforts.

Treatment plant operations, variations in wastewater characteristics, and changes in upstream areas will be important to note during monitoring. Any significant variation in wastewater loadings can upset the natural tendency for wetlands to equilibrate. During periods of upset, a wetland is most prone to adverse environmental effects.

6.2 MANAGEMENT OF SEAFOOD-PROCESSING WASTEWATERS UTILIZING SALTWATER WETLANDS

Many of the concepts covered in Section 6.1 for municipal wastewater also apply to seafood processing wastewaters. However, instead of secondary treatment of seafood wastewater prior to discharge to a wetland, Best Conventional Pollutant Control Technology (BCT) is a pre-requisite. In addition, wastewater flows from seafood processors can be extremely irregular unlike flows from most wastewater treatment plants. The effects of seafood processing discharges on wetland areas have not been documented, primarily because very few seafood-processing discharges released to wetland areas have been studied.

This section discusses those aspects of discharging seafood-processing wastewaters to a wetland that differ from those of municipal wastewaters.

Issues of Interest

- . How do seafood-processing wastewaters differ from municipal wastewaters?
- . How do the effects of seafood-processing wastewater discharges differ from those of municipal discharges?

6.2.1 Planning and Preliminary Design

A number of variables are evident when considering the discharge of seafood processing wastes:

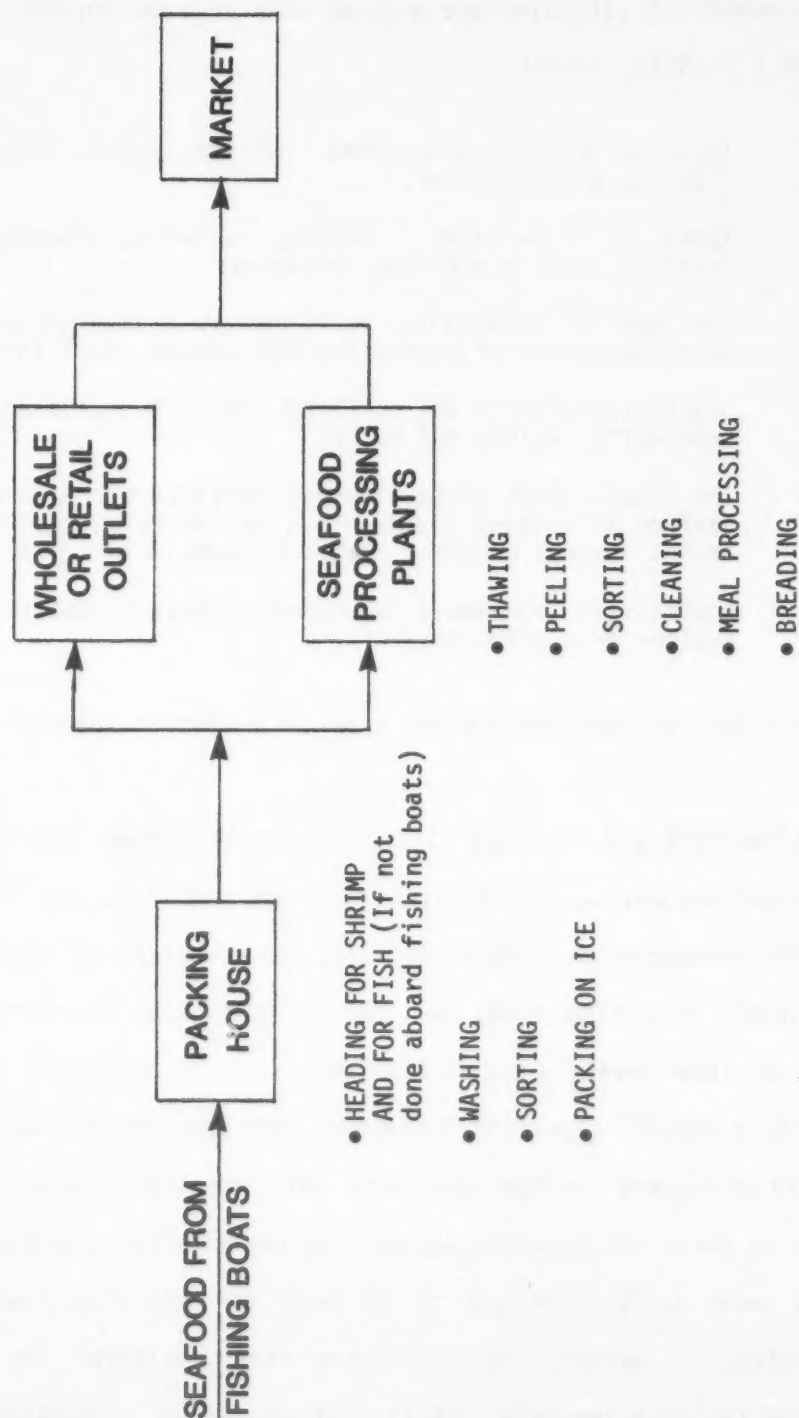
- . Types of seafood processed: shrimp, crabs, clams, oysters, fish, or a combination;
- . Types of processing: peeling, sorting, thawing, cleaning, fileting, meal processing, breading;
- . The type of processing performed at a seafood plant depends upon the extent of processing done aboard the fishing vessels;
- . Quantities of fish and shellfish that are processed, which vary seasonally, weekly and daily;
- . The extent that house-cleaning activities are conducted at a seafood processing plant (i.e., solids being washed into floor drains instead of being placed in garbage cans); and
- . Adequacy of wastewater treatment processes associated with the seafood processing facility.

Figure 6.2-1 outlines the typical steps in preparing seafood for market.

Brinsfield and Phillips (1977) present data from 1975 and 1976 for 18 seafood processing facilities in Maryland that show very high residual chlorine concentrations (30 to 90 mg/l) and simultaneous mean total coliform levels exceeding 1,000 per 100 ml (a typical standard for median total coliform levels in shellfish waters is 70 organisms per 100 ml). Brinsfield and Phillips (1977) conclude that the seafood waste chlorination methods used in Maryland were not effectively reducing coliform counts to shellfish water standards. At the same time, residual chlorine values were quite high (up to 89 mg/l for six blue-crab processing facilities). Options for improving this condition include either improved chlorination-dechlorination or use of an alternative disinfection

TYPICAL STEPS INVOLVED IN PREPARING SEAFOOD FOR MARKET

FIGURE 6.2-1



tant (e.g., ozone or UV radiation). Adequate disinfection may be more necessary for discharges to saltwater wetlands than for discharges to freshwater wetlands, if shellfish-harvesting waters exist adjacent to the saltwater wetlands.

Wastewaters are generated from many different seafood processing activities. As an example, the types of wastewater generated during shrimp processing are shown in Figure 6.2-2. Some of these steps can be done aboard a shrimp boat, depending upon the intensity of shrimp harvesting and the type of boat.

The following discussion for shrimp processing does not necessarily apply to other types of seafood. However, the variations in wastewater quantities shown for shrimp may be typical of other seafood operations. Table 6.2-1 lists basic processing steps for other types of seafood.

Two types of shrimp handling facilities are utilized; packing houses and processing plants. Shrimp are often de-headed at sea, except during peak harvesting periods when at least part of the catch is de-headed at the packing houses. A typical shrimp packing house handles 1,000 to 1,500 pounds of shrimp per day. Discharges of wastewater can range from 1,500 to 9,000 gallons per day (Gates et al., 1982). Shrimp processing plants, on the other hand, handle 10,000 to 30,000 pounds of shrimp daily and generate 100,000 to 300,000 gallons of effluent per day (approximately 10 gallons per pound of shrimp processed; Gates et al., 1982).

FIGURE 6.2-2

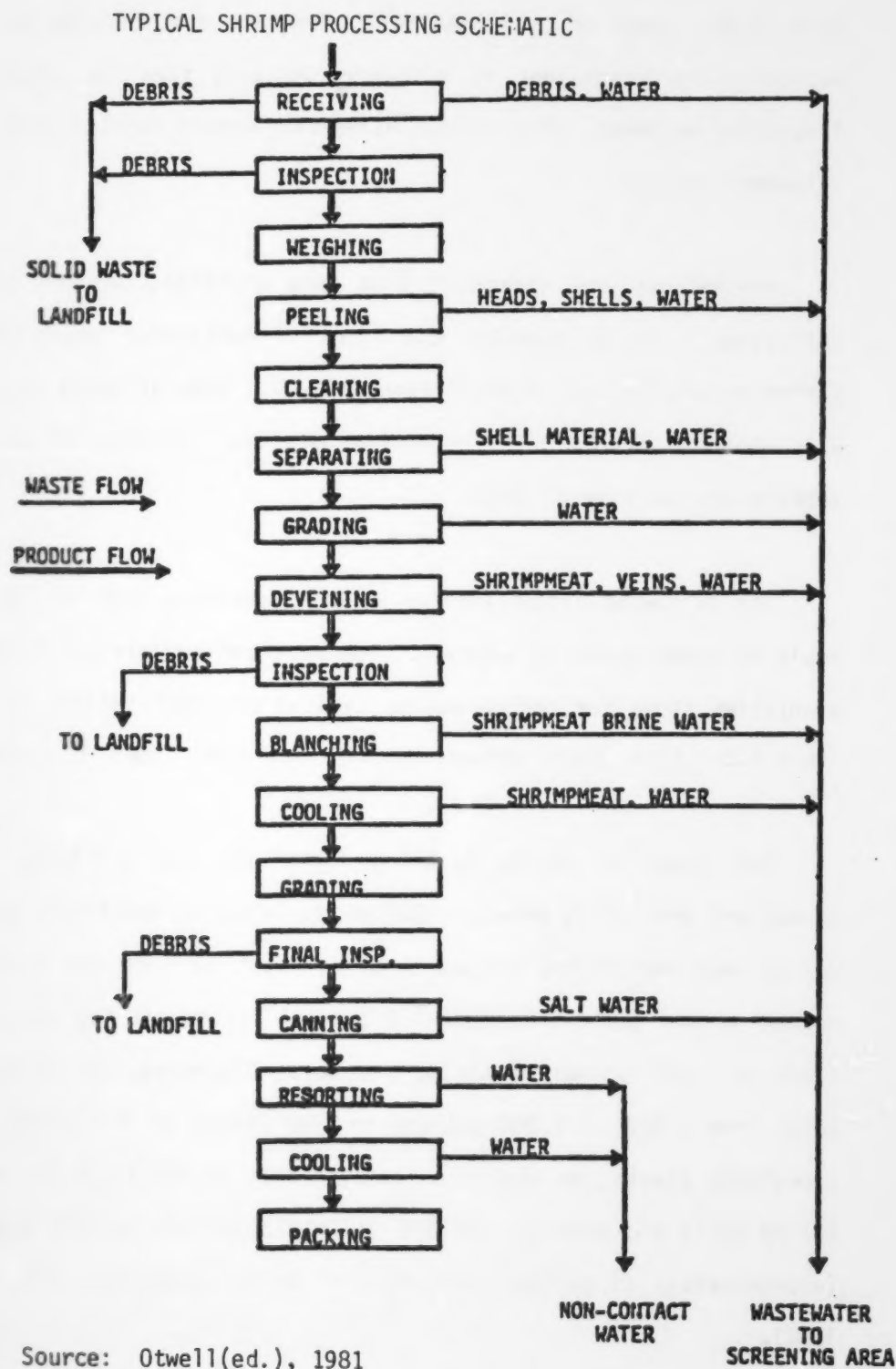


TABLE 6.2-1
CHARACTERISTICS OF VARIOUS TYPES
OF SEAFOOD PROCESSING

<u>Type of Seafood</u>	<u>Processing Step</u>	<u>Wastes From Process</u>	<u>Comments</u>
Blue Crab	Receiving Steam cooking Cooling Meat picking Packaging	Water Cooking condensate Water Shells, legs ---	Water usage is small throughout blue crab processing plants, except for plants with claw picking machines. Effluent from claw picking machine operations are not as biodegradable as effluent from other crab processing plants.
Shrimp	See Figure 6.2-2	See Figure 6.2-2	Portions of catches in the southeastern U.S. are often de-headed at sea. Wash water from rollers can be fresh water or salt water.
Finfish	Receiving Washing, separating, icing Sorting Grading Re-icing	Water, fish wastes Water, scales --- --- ---	For three plants surveyed in North Carolina, average wastewater quantities were 1.3 gallons per pound of raw fish processed. Five-day BOD of the untreated effluent at the same three plants averaged 190 mg/l.
Oysters	Blow tanks are much of wastewater	---	For three plants surveyed in North Carolina, average wastewater quantities were 3.0 gallons per pound of oyster meat. Five-day BOD of the untreated effluent at the same three plants averaged 400 mg/l.

TABLE 6.2-1
CHARACTERISTICS OF VARIOUS TYPES
OF SEAFOOD PROCESSING
(Continued)

<u>Type of Seafood</u>	<u>Processing Step</u>	<u>Wastes From Process</u>	<u>Comments</u>
Scallops	Receiving Shocking Evisceration	Most wastes are generated during evisceration	For twelve plants in North Carolina, untreated effluent volumes ranged from 7 to 15 gallons per pound of scallop meat. Five-day BOD concentrations in untreated effluent ranged from 700 to 2,700 mg/l.

Information sources: U.S. EPA, 1974 and Otwell, 1980.

The following characteristics correspond to screened wastewater from a plant that peels, sorts, thaws and cleans seafood which was sampled during a randomly selected day of operation (Gates et al. in Otwell, 1981):

Biochemical oxygen demand (BOD) mg/l	280
Suspended solids, mg/l	90
Ammonia nitrogen, mg/l	2.2
Total coliforms, per 100 ml	94,000
Fecal coliforms, per 100 ml	6,700

mg/l - milligrams per liter
ml - milliliters

Table 6.2-2 provides wastewater quality information for a large combined seafood operation following wastewater treatment. Variations in processing plant effluent are due to variations in activities that, by coincidence, were noted in samples taken during different tidal periods.

Information in Table 6.2-2 indicates that effluent concentrations from seafood-processing plants can vary considerably depending primarily upon the quality of wastewater being treated. In addition, treated wastewater characteristics shown in Table 6.2-2 are of lower quality than the receiving waters. Ammonia-nitrogen values were significantly higher in the effluent than in the receiving waters. Fecal coliform counts for the processing plant effluent exceeded the Georgia guidelines for waters used for recreation, fishing, shellfish, game, fish propagation and other aquatic life, but were within guidelines of 5,000 fecal coliforms per 100 ml designated for agricultural and navigational waters. Dissolved oxygen levels were below the Georgia Environmental Protection Division minimum of 4.0 mg/l. However, because values below 3.0 mg/l were also measured

TABLE 6.2-2

ANALYSIS OF SELECTED PACKING HOUSE AND PROCESSING PLANT
EFFLUENTS IN THE VICINITY OF BRUNSWICK, GA
DURING JULY-AUGUST 1979

Station	pH	Biochemical Oxygen Demand, ¹ mg/l	Suspended Solids mg/l	Turbidity, Formazin Turbidity Units	Ammonia Nitrogen, mg/l	Salinity, Parts per Thousand	Dissolved Oxygen, mg/l	Total Coliforms, MPN ² per 100 ml	Fecal Coliforms, MPN ² per 100 ml
Packing House Effluent (1 sample)	7.9	420	13	5	0.2	2	4.3	150	43
Processing Plant Effluent									
a. During a July 1979 low tide	7.6	300	120	30	2.0	0	7.6	24,000	2,400
b. During a July 1979 high tide	7.6	260	60	24	1.6	-	7.5	2,400	1,100
c. During an Aug. 1979 low tide	8.5	280	98	-	2.4	3	5.6	240,000	11,000
d. During an Aug. 1979 high tide	7.7	270	80	32	2.6	0	7.6	110,000	2,400

Footnotes:

1. Biochemical oxygen demand values are probably five-day BOD values. The study report does not define the time between sampling and BOD analyses.
2. MPN is defined as most probable number of organisms.

General Notes:

1. Reference: Gates et al., 1982
2. Values presented are rounded from values presented in study report.
3. Effluent flows were 215,000 gallons per day from the processing plant. Packing house effluent resulted from heading of approximately 1,000 pounds of rock shrimp.

in undeveloped Georgia estuarine areas, the low dissolved oxygen levels cannot be attributed exclusively to processing effluent. The biochemical oxygen demand (BOD) load from this seafood-processing effluent was shown to be equivalent to the organic materials generated by a 302-square meter plot of salt marsh, and the ammonia-nitrogen levels were greater than, but the same order of magnitude as, natural runoff from marsh land (Gates et al., 1982).

Methods to reduce the amount of waste loads reaching treatment facilities can be quite simple, such as collecting solids for solid waste disposal. Manufacturing of secondary products from wastes generated during primary processing is feasible for most if not all seafood types.

6.2.1.1 Seafood Wastewater Treatment

Various wastewater treatment options have been utilized to treat seafood processing wastewaters:

- . Screening;
- . Dissolved air flotation (DAF) or other types of air flotation treatment;
- . Other forms of physical-chemical treatment;
- . Biological treatment: activated sludge variations, trickling filter(s), rotating biological contactor; and
- . Discharge to nearby municipal wastewater treatment plant.

Physical-chemical wastewater treatment is more appropriate for seafood wastewaters than biological treatment, because physical-chemical processes are more amenable to intermittent processing and also less

space-intensive. However, physical-chemical processes are usually less efficient when handling high BOD and suspended solids loadings. Descriptions of the various physical-chemical treatment options are given in Table 6.2-3. Screening and air flotation are utilized extensively by food processing industries for wastewater treatment. Air flotation treatment requires qualified, trained personnel preferably with a pre-conceived operation and maintenance plan. General concerns or problems associated with any treatment process used to treat seafood-processing wastewaters are as follows: intermittent operation (e.g., 4 to 8 hours per day for 120-150 days per year for shrimp processing along the Gulf coast), long start-up and shut-down times each day, sludge with low solids content, and variation of waste concentrations entering the treatment process(es).

Wastewater treatment requirements are based on Best Conventional Pollutant Control Technology (BCT) for control of BOD, total suspended solids, fecal coliforms, pH, oil and grease. BCT replaced Best Available Treatment Economically Achievable (BAT). The BCT guidelines (Table 6.2-4) are resulting in concern within the seafood processing industry regarding wastewater treatment costs. BCT regulations have not been promulgated; proposed draft regulations are due to be published for public review by early 1984 (U.S. EPA, personal communication, September 1983). Brinsfield and Phillips (1977) conclude that static screens can meet limitations (as of 1978) for clam processors and shrimp processors in Maryland. Screens are not sufficient to meet limitations (as of 1978) for blue crab and fish processors in Maryland.

TABLE 6.2-3

DESCRIPTIONS OF PHYSICAL-CHEMICAL TREATMENT
PROCESSES UTILIZED TO TREAT SEAFOOD PROCESSING WASTEWATERS

<u>Treatment Process</u>	<u>Description of Process</u>
Screening	Solid and soluble constituents are separated from wastewater by a mesh of fibers as the wastewater flows perpendicular to the mesh. Many different types of screens can be utilized.
Sedimentation	Solid-liquid separation is accomplished by allowing solids to settle from liquid. Addition of chemicals can enhance removal of solids and soluble constituents.
Air flotation (vacuum, dispersed or dissolved)	Buoyant air lifts wastewater constituents to the water surface. Surface sludges are then skimmed, collected and dewatered. Chemicals can be added to enhance treatment efficiency. Flow can also be recycled to avoid process interruptions.
Chemical oxidation	Chlorine and ozone can oxidize organic matter thereby removing BOD and chemically converting other compounds. High chemical costs restrict use of this treatment process.

TABLE 6.2-4
TECHNOLOGY ASSESSMENT FOR THE
SEAFOOD PROCESSING INDUSTRY IN THE CONTIGUOUS U.S.

Segment	BAT	BCT	BCT Rationale
Catfish	Aerated Lagoon	Aerated Lagoon	Same as BAT
Mechanized Blue Crab	Aerated Lagoon	DAF	Technology Transfer from West Coast Crab*
Shrimp	DAF	DAF	Data from Full-scale Facilities
Tuna	Roughing Filter and Activated Sludge	DAF	Data from Full-scale Facilities
Mechanized Salmon	DAF	DAF	Data from Full-scale Facilities
Mechanized Bottom Fish	DAF	DAF	Technology Transfer from Tuna
Mechanized Clam	Aerated Lagoon	Grit Removal and DAF	Technology Transfer from S/C Oyster
Steamed/Canned Oyster	Aerated Lagoon	Grit Removal and DAF	Data from Full-Scale Facilities
Sardine	DAF**	DAF*	Data from Full-Scale Facilities
Herring Fillet	DAF	DAF	Technology Transfer from Mechanized Salmon

* Performance data was collected during a pilot-scale study.

** Treatment of fresh water stream only.

NOTE: Both BAT and BCT include in-plant measures.

DAF - Dissolved Air Flotation

Source: Ertz in Otwell (ed.), 1981

The costs for treating seafood processing wastewaters vary with the volume of seafood processed, type of treatment and method of operation.

6.2.1.2 Other Planning Considerations

Wastewater disposal options are the same for seafood processors as they are for municipal dischargers. However, wide variations in discharge characteristics that can occur at a seafood processing plant over time must be considered. Decisions about the suitability of seafood wastewaters entering wetlands need to be based on the type of information presented in both Sections 6.1 and 6.2 of this report. The function and use of the wetland that may receive the wastewater should be considered as part of the processing of assessing the suitability of any wastewater discharge.

Changes in water conservation, by-product conservation, seafood processing, or wastewater treatment techniques at processing plants can alter the effect of treated wastewater on the receiving environment. Improved by-product conservation, in particular, would reduce waste concentrations in wastewater effluent. The agency responsible for maintaining the receiving environment should be aware of any changes at a seafood processing plant in order to better assess environmental impacts.

6.2.2 Design and Installation

Selections of sizes for treatment facilities should be based on costs, waste flow rates and variations, waste quality characteristics, projections of seafood processing expansions, and effects of treated

wastes on the receiving environment. Capacity for storage prior to treatment could also be provided in order to reduce fluctuations of quantities of wastewater entering the treatment facility.

Selection of treatment processes should be based on pilot-scale, laboratory test results showing the treatability of the wastewater with various types of processes. Each of the potential wastewater treatment processes have different design considerations as outlined in Table 6.2-5. Many design values are variable depending upon results of bench-scale laboratory studies of wastewater treatability or depending upon wastewater volumes and characteristics. Treatment of seafood-processing wastewaters has not been studied to the extent that treatment of municipal wastewaters has been studied.

The need for chlorination or some other form of disinfection is one type of decision for the seafood processor and the regulatory agency to make. Chlorination can result in various efficiencies of killing pathogenic microorganisms depending upon the degree of wastewater treatment prior to chlorination, the pH and salinity of the wastewater and other factors.

Design and installation of wastewater storage and disposal facilities should follow the same guidelines outlined in Section 6.1.2. All of the considerations associated with costs, environmental impacts, operation and implementation of storage and disposal facilities presented in Section 6.1.2 apply to seafood-processing wastewaters as well.

TABLE 6.2-5

DESIGN PARAMETERS FOR TYPES OF SEAFOOD
PROCESSING WASTEWATER TREATMENT

<u>Type of Treatment</u>	<u>Design Parameter</u>	<u>Range of Design Parameter</u>	
		<u>Number</u>	<u>Units</u>
Screening	Mesh size	30 to 300	mesh ¹
	Speed of rotating or vibrating drum (if applicable)	Variable	
	Angle of inclination (if applicable)	45 to 60	degrees from horizontal
Sedimentation	Overflow rate ²	Variable	---
	Water depth	Usually 6 to 10	feet
	Detention time	30 to 120	minutes
	Chemical feed type (if used)	Alum or iron compound	---
	Chemical feed rate (if applicable)	Variable depending upon jar test results	---
Chemical oxidation (higher dosages of oxidants than for disinfection) or disinfection	Selection of oxidant	Chlorine, ozone, permanganate	---
	Method and costs to obtain oxidant	Variable	---
	Oxidant-wastewater mixing time and energy use	Usually 1 to 5 for mixing	Minutes
	Size of oxidant-wastewater contact basin	Variable	---
	Contact detention time	Usually 30 to 60	Minutes

TABLE 6.2-5
DESIGN PARAMETERS FOR TYPES OF SEAFOOD
PROCESSING WASTEWATER TREATMENT
(Continued)

<u>Type of Treatment</u>	<u>Design Parameter</u>	<u>Range of Design Parameter</u>	
		<u>Number</u>	<u>Units</u>
Air flotation	Type of system	Vacuum, dispersed air or dissolved air	---
	Pressure of wastewater prior to release to tank (dissolved air flotation only)	30 to 50	Pounds per square inch (psia)
	Type and quantities of chemical additives (coagulants, pH adjustment)	Variable	---
	Size of flotation tanks (water depth, detention time)	Variable	---
	Air diffusion rates	Variable	---

Footnotes: ¹ Sieve openings for a 30-mesh sieve are approximately 600 microns (approximately 0.024 inch). Sieve openings for a 300-mesh sieve are approximately 50 microns (approximately 0.002 inch).

² Overflow rate is defined as the volume of wastewater per day per surface area of a sedimentation basin.

Data Sources: U.S. EPA, June 1974; Brinsfield and Phillips, 1977 and Otwell, 1981.

6.2.3 Operation, Maintenance, Repair and Monitoring

Most of the operation, maintenance, repair and monitoring considerations presented earlier in Sections 6.1.3 and 6.1.4 are also applicable to seafood-processing wastewaters. Proper planning and design can be nullified by improper operation, maintenance and repair. The lack of information regarding the effects of seafood-processing wastewaters on wetlands makes proper operation, maintenance, repair and monitoring particularly important. The cost savings associated with avoiding treatment system overhauls by properly operating, maintaining and repairing a facility could be stressed to seafood processors. An effort by environmental agencies may be needed to make seafood processors aware of the value of operation, maintenance and repair activities.

Promotion of monitoring activities could be particularly difficult. Seafood processors can contend that proper operation, maintenance and repair is enough of an effort on their part to avoid adverse environmental impacts. The appropriate state environmental agency may need to be responsible for monitoring activities with support from seafood processors. Furthermore, the tendency for seafood-processing discharges to be released periodically, rather than continuously, could further complicate the assessment of monitoring results.

6.3 ENGINEERING-RELATED ISSUES AND OPTIONS

In summary, a number of issues remain unresolved in association with the engineering of saltwater wetland wastewater systems. These issues include flow and chemical transport complexities of saltwater wetlands as

well as considerations that vary with different saltwater wetland areas. Table 6.3-1 lists a number of important issues that need to be resolved with additional research and/or judgments and options. Engineering options can be developed to address many issues. By preparing an inventory of all options and determining how well they address the issues, the reasonableness of allowing discharges to saltwater wetlands can be estimated.

TABLE 6.3-1

ENGINEERING-RELATED ISSUES AND
OPTIONS FOR SALTWATER WETLANDS

ISSUES

- Determining appropriate wetland hydraulic, organic, and nutrient loading rates;
- Estimating wastewater detention time within wetlands;
- Estimating levels of metal and organic compounds in soils and vegetation that would avoid adversely affecting the wetland system;
- Estimating quantity and quality of wastewater entering coastal waters downstream from the wetland;
- Determining seasonal ecosystem variations and effects on wastewater treatment and detention time;
- Determining the ability of saltwater wetlands to provide long-term wastewater renovation;
- Determining the compatibility of pre-treated industrial discharges;
- Determining water depths that are appropriate for propagation of existing vegetation;
- Determining alterations to habitat for threatened or endangered species;
- Use of chlorine or other disinfectants in terms of public health and ecosystem toxicity;
- Determining the effect of saline waters on equipment and O&M needs;
- Determining the importance of tidal effects on pollutant removal ability;
- Determining the effect of a freshwater wastewater discharge on a saltwater wetland environment; and
- Determining the vulnerability of saltwater wetland alternatives to coastal storms and tidal surges.

TABLE 6.3-1
(Continued)

ENGINEERING-RELATED ISSUES AND
OPTIONS FOR SALTWATER WETLANDS

SOME OPTIONS (continued)

- . Multi-port or gate distribution of wastewater;
- . Containment dikes, berms, weirs to separate wetland into plots;
- . Mosquito control (as needed);
- . Plant harvesting and by-product production;
- . Introduction and promotion of free-floating aquatic plants
 - sale and transport of plants are limited legally,
 - free-floating vegetation can not survive in tidal areas which are not continuously covered with water,
 - many types may not be able to tolerate saltwater conditions.
- . Spraying of wastewater;
- . Planned resting periods when no wastewater would be discharged;
- . Dechlorination: pond capacity or use of sulfur dioxide following chlorination; and
- . Use of a back-up or alternate discharge mechanism.

6.4 LITERATURE CITED

- American Public Health Association (APHA) et al., 1975. Standard Methods for the Examination of Water and Wastewater. Fourteenth edition.
- Brinsfield, R.B. and D.G. Phillips. August 1977. Waste Treatment and Disposal from Seafood Processing Plants. EPA-600/2-77-157. Ada, OK, August 1977.
- Brown and Caldwell, September 1982. Preliminary Design and Marine Survey for Ocean Outfall: Dare County, North Carolina. Prepared for Dare County and the U.S. Environmental Protection Agency in association with Law Engineering Testing Company.
- Chan, E., T.A. Bursztynsky, N. Hantzsche and Y. Litwin, September 1982. The Use of Wetlands for Water Pollution Control. EPA 600/2-82-086. Cincinnati, OH.
- Conner, W.H., J.H. Stone, L.M. Bahr, V.R. Bennett, J.W. Day, Jr., and R.E. Turner. 1976. Oil and gas use characterization, impacts and guidelines. National Oceanic and Atmospheric Administration (NOAA-77021602). 148 pp.
- Edzward, J.K., J.B. Upchurch and C.R. O'Melia, October 1972. Coagulation in Estuaries. Presented at the 45th Annual Conference of the Water Pollution Control Federation, Atlanta, GA.
- Gates, K.W., B.E. Perkins, J.G. EuDaly, A.S. Harrison and W.A. Bough, 1982. Assessment of Seafood Processing and Packing Plant Discharges and their Impacts on Georgia's Estuaries. Georgia Marine Science Center. Skidaway Island, GA. Technical Report Series Number 82-3.
- Hammer, D.E. and R.H. Kadlec, April 1983. Design Principles for Wetland Treatment Systems. EPA 600/2-83-026. Ada, OK.
- Hyde, H.C. and R.S. Ross, 1980. Technology Assessment of Wetland for Municipal Wastewater Treatment. EPA 68-03-3016. U.S. EPA, Cincinnati, OH.
- Klapow, L.A. and R.H. Lewis, 1979. Analysis of Toxicity Data for California Marine Water Quality Standards. Journal of the Water Pollution Control Federation, Vol. 51, No. 8.
- Meo, M., J.W. Day, Jr., and T.B. Ford, November 1975. Overland Flow in the Louisiana Coastal Zone of the Sea Grant Development Center for Wetland Resources, L.S.U., Baton Rouge, LA.
- Nelson, R.W. and E.C. Weller. 1984. A better rationale for wetland management. Environmental Management, Vol. 8, No. 4. Springer-Verlag, New York, Inc., New York. pp. 295-308.

LITERATURE CITED (continued)

- Otwell, W.S., February 1981. Seafood Waste Management in the 1980's: Conference proceedings, September 23-25, 1980. Report Number 40, Florida Sea Grant College.
- Reeco, Renee, U.S. EPA, personal communication, Washington, DC. September 1983.
- Robert Snow Means Company, Inc., 1983. Means Construction Cost Data, Kingston, MA.
- Stewart, R.K. and D.R. Tangarone, 1977. Water Quality Investigation Related to Seafood Processing Wastewater Discharges at Dutch Harbor, Alaska, October 1975 - October 1976. U.S. EPA, Seattle, WA. EPA 910/8-77-100.
- Stowell, R., R. Ludwig, J. Colt and G. Tchobanoglous, August 1980. Toward the Rational Design of Aquatic Treatment Systems, ASCE Spring Convention, Portland, OR. April 14-18, 1980.
- Tarquin, A.J., June 1976. Treatment of High Strength Meatpacking Plant Wastewater by Land Application, EPA-600/2-76-302. U.S. EPA, Ada, OK.
- U.S. EPA, June 1971. CRESA and Engineering-Science of Alaska - Pollution Abatement and By-Product Recovery in Shellfish and Fisheries Processing. U.S. EPA 11060FJQ.
- U.S. EPA, June 1974. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Catfish, Crab, Shrimp, and Tuna Segment of the Canned and Preserved Seafood Processing Point Source Category. 440/1-74-020-a.
- U.S. EPA, May 1975. Finger-fill Canal Studies: Florida and North Carolina EPA-940/9-76-017.
- U.S. EPA, July 1976. Quality Criteria for Water. Office of Water and Hazardous Materials, Washington, DC.
- U.S. EPA, September 1979. Aquaculture Systems for Wastewater Treatment: Seminar Proceedings and Engineering Assessment. EPA 430/9-80-006. Washington, DC, September 1979.
- U.S. EPA, February 1980. Innovative and Alternative Technology Assessment Manual. Office of Water Program Operations. Washington, D.C. MCD-53; EPA 430/9-78-009.
- U.S. EPA, February 1983. Freshwater Wetlands for Wastewater Management EIS, Phase I Report. U.S. EPA, Atlanta, GA.

7.0 SUMMARY OF INSTITUTIONAL, SCIENTIFIC AND ENGINEERING CONSIDERATIONS

The key institutional, scientific and engineering considerations that affect the use of saltwater wetlands for wastewater management are summarized. Additionally, areas that require further study are identified.

7.1 INSTITUTIONAL CONSIDERATIONS

Institutional control of wastewater management in saltwater wetlands is carried out at both the federal and state level. Federal involvement is through both funding and regulatory programs. The scope of involvement varies among these programs from a limited advisory role to full-scale review and issuance of discharge permits. The scope of control also varies widely at the state level.

7.1.1 Federal Involvement

Federal involvement with wetland discharges takes place primarily through four programs, the Water Quality Standards Program, the National Pollutant Discharge Elimination System (NPDES) Permit Program, the 201 Construction Grants Program and the Section 404 Dredge and Fill Permit Program, all promulgated under authority of the Clean Water Act.

The water quality standards program provides for a mechanism which defines the water quality goals of a water body and by which criteria are established to protect or achieve those uses. Standards are adopted to protect public health or welfare, enhance the quality of water and serve the purposes of the Clean Water Act. Water quality standards should, wherever attainable, provide for the protection and propagation of fish, shellfish and wildlife and provide for recreation in and on the water.

The NPDES program is a process for permitting point source discharges into waters of the United States including saltwater wetlands. All states within the project area except Florida have been delegated responsibility for the NPDES program by the United States Environmental Protection Agency (USEPA).

The 201 Construction Grants Program is the vehicle for providing federal funding for the development of municipal wastewater facilities. The 201 Program only pertains to saltwater discharges if a municipality wishes to receive a federal grant to assist with developing a facility that would treat and discharge municipal wastewaters to saltwater wetlands. Such projects may be eligible for funding under the 201 Program. The possibility of receiving federal funds could result in a more detailed evaluation of environmental impacts. Each of the study area states implements the 201 Program under USEPA authority. The manner in which funds are available varies from state to state.

The Section 404 Dredge-and-Fill Permit Program administered by the Army Corps of Engineers (COE) is another federal regulatory program affecting wetland discharges. A Section 404 permit may be required if dredging and filling will take place as a result of construction of wastewater facilities in wetland areas.

The USEPA shares a responsibility with the COE under Section 404 with respect to any dredge and fill activity, including operations in wetlands. Additionally, the Department of the Interior, Fish and

Wildlife Service (FWS), and the Department of Commerce, National Marine Fisheries Service (NMFS) share permit application review responsibilities in terms of potential environmental impact on the resources of saltwater wetlands. The roles of both these agencies are purely advisory.

7.1.2 State Involvement

Each state has the authority to regulate activity in their respective coastal zones. The means of regulation include enforcement of water quality criteria, issuance of discharge permits (with the exception of Florida) and project prioritization for construction grant funding. A lack of consistency exists among the states in several areas which influences the effectiveness of wetland permitting along the entire coastal zone. A number of key issues result from the manner in which the states carry out these programs.

7.1.2.1 Water Quality Standards

The key issue concerning water quality standards is whether a state has a specific classification for saltwater wetlands and whether numerical criteria have been established that recognize the natural water quality characteristics of wetlands. Not all the states within USEPA Region IV have established specific classifications for saltwater areas. All of these states, however, do recognize a separate classification for shellfishing waters. The USEPA Region IV states, except Georgia and Mississippi, have allowances for lower background levels for dissolved oxygen in wetland waters. Exceptions are also made for other parameters in some states. However, except where such allowances are made for

wetlands, the criteria applied are likely to be the same as for adjacent open waters. This may result in stringent criteria for wetlands and discourage the use of wetlands for discharges. An alternative would be to develop site-specific criteria. Some of the states have experimented with this approach.

7.1.2.2 NPDES Permits

The main issue regarding saltwater discharges is how effluent limits are set for wastewater discharge permits. Based on the requirements of the Clean Water Act, any discharge to saltwater wetlands would need to receive a minimum of secondary treatment. Where the receiving body is defined as water quality limited, more stringent standards would need to be met. One of the problems is that in many cases there has been no determination as to whether a particular wetland is effluent limited or water quality limited. It is likely that the finding for the adjacent water body would be applied. If the decision is that the wetland is water quality limited, the problem of how to determine an effluent limitation is raised. Wetland effluent limitations are difficult to simulate mathematically due to their unique hydrological and biological characteristics.

The states' responses to this situation have varied. Some prescribe only secondary treatment in all wetland areas. Some use conventional water quality models, others use modified models, still others use experience from past permit reviews.

7.1.2.3 Construction Grants Program

The primary issues under the 201 Construction Grants Program concern eligibility, funding levels and project prioritization. All of the states within USEPA Region IV indicate that they would consider a project which incorporates a wetland discharge to be grant eligible. Components of the project that are eligible are, however, unclear. The approach to funding levels varies, however. USEPA Region IV states do not give a specific preference to wetland discharge projects, but most consider such projects to be either "alternative" or "innovative" and thereby eligible for separate funds set aside for these types of projects. A few of the states including Georgia and Florida give some preference to "innovative" or "alternative" technology projects in setting funding priorities. In South Carolina one of the ranking factors would be rated higher for wetland projects.

7.1.2.4 Other Programs

There are other programs that are not specifically focused on water quality which could impact saltwater discharge projects. Each of the six states administers some form of coastal area management program. In Mississippi, Alabama, Georgia and South Carolina a coastal permit would be required for a wetland discharge. North Carolina specifically prohibits certain activities (which may include the use of wastewater facilities) from some coastal areas. In Florida, construction within the coastal zone would require additional state permits.

7.2 SCIENTIFIC CONSIDERATIONS

Components of saltwater wetland ecosystems include geomorphology, vegetation, hydrology, water quality and wildlife. Biotic and abiotic factors operate in dynamic equilibrium and the characteristics, functions and processes of saltwater wetlands are variable and interrelated. The discharge of municipal or seafood-processing wastewater has the potential of disrupting the integrity of these wetlands. However, the potential for positive effects must also be considered.

Five major factors were identified as being important when evaluating a potential saltwater wetlands discharge:

- Erosion would be expected to vary with characteristics of the soil, density of vegetation and effluent rates per unit of marsh surface area.
- Nutrients may affect the marsh vegetation and/or the estuary. The types or amounts of nutrients entering the marsh would depend on the characteristics of the effluent, while their pathways in the marsh would depend on such factors as sediment characteristics, uptake rates by vegetation and frequency of tidal inundation.
- Toxic substances and pathogens entering the marsh will also vary with the quality of the effluent. This factor is particularly relevant for consideration because of public health implications.
- Vegetation may be affected by several parameters associated with wastewater disposal including decreased salinity, continual soil saturation and nutrient loading. A primary concern is that shifts in plant species composition or distribution may occur in the marsh.
- Wildlife may be affected if shifts in the vegetation occur that alter food availability, nesting sites, cover or similar habitat parameters. Wildlife could also be affected by toxic substances introduced with treated effluent. The occurrence of threatened and endangered animal species is another reason for wildlife to be a factor for consideration.

7.3 ENGINEERING CONSIDERATIONS

Numerous factors are important to consider as a wetland-wastewater system is being planned, designed, installed, operated, maintained and monitored (Tables 7.3-1 and 7.3-2). Planning factors are more numerous than the other types of factors because planning, by definition, encompasses all subsequent engineering activities.

To date, observed practices seem to indicate that wastewater treatment plant (WWTP) discharges are usually located at the edge of a wetland area. Little or no monitoring of the effluent occurs once it enters the wetland. As a result, the wetland which receives wastewater is seldom evaluated during any engineering stage: planning, design, installation, operation, maintenance-repair or monitoring. This hands-off philosophy also holds down the financial burden of WWTP operations, which is an important objective for both municipal managers and seafood-processing industries. Moreover, existing complexities regarding wetland hydrology and wetland physical-chemical-biological processes cannot be addressed without relatively extensive monitoring and wetland maintenance efforts.

7.4 KEY FACTORS

Key scientific and engineering factors for evaluating saltwater wetlands as potential wastewater discharge sites are geology, hydrology and water quality. The key institutional factor is regulatory control.

- Geological components refer to composition of the sediments, particularly as they relate to porosity (permeability) and movement of water or wastewater into or through the sediments.
- Hydrological components refer to the discharge volume and rate(s) of application, as well as to tidal fluctuations,

TABLE 7.3-1
ENGINEERING FACTORS PERTINENT TO UTILIZING WETLANDS
FOR ANY TYPE OF WASTEWATER MANAGEMENT

Factor (for consideration)	Planning	Design	Installation	Operation	Maintenance	Monitoring	Comments
Level of treatment prior to discharge to wetland and from wetland	x	x				x	Minimum requirement is secondary treatment prior to discharge to wetland
Evaluation of other wastewater disposal options besides use of wetlands	x						At many locations, no other reasonable alternative may exist
Evaluation of various wetland disposal sites	x						Usually wastewater is discharged adjacent to the wastewater treatment plant
Other use(s) of wetland besides wastewater management	x						Assessing effects of numerous wetland usages is usually the responsibility of regulatory agencies
Estimating best time of year for installation activities within a wetland (if any)	x		x				
Impacts of wastewater on life forms, soils and groundwater	x					x	Seldom evaluated by dischargers
Advantages and disadvantages of chlorine usage, other forms of disinfection and dechlorination	x	x				x	Seldom evaluated by dischargers
Wastewater loading rates (hydraulic, organic and nutrient loadings), detention time and flow paths	x	x				x	Seldom evaluated by dischargers
Treatment rates for various wetlands on a seasonal basis	x					x	Not well understood but believed to be variable
Method for applying wastewater to a wetland	x	x	x	x	x		Usually a single pipe discharge at the edge of a wetland is utilized. Energy costs and pipeline placement are primary considerations Financial burden is usually minimized
Financial burden in comparison to environmental impacts, operation and implementation	x						
Providing and effectively utilizing wastewater storage to enhance the wetland	x	x	x				Seldom evaluated by dischargers
Techniques for enhancing wetland use through wetland maintenance	x			x	x		Seldom evaluated by dischargers

TABLE 7.3-1
(continued)
ENGINEERING FACTORS PERTINENT TO UTILIZING WETLANDS
FOR ANY TYPE OF WASTEWATER MANAGEMENT

Factor (or consideration)	Planning	Design	Installation	Operation	Maintenance	Monitoring	Comments
Use of back-up wastewater disposal systems (e.g., other wetland areas or perhaps land application at upland areas)	x	x	x	x			Seldom evaluated by dischargers; options are limited by distance to alternative discharge location and associated costs
Minimizing wetland disturbances with installation, operation and maintenance of wetland-wastewater system	x		x	x	x		
Reliability for long-term wastewater management	x					x	Not well understood, particularly for salt-water wetlands
Extent to which ecosystem can be modified without adversely affecting other wetland uses	x					x	Not well understood, particularly for salt-water wetlands
Artificial creation of wastewater management	x	x	x	x	x	x	Seldom, if at all, considered in detail for saltwater wetland; regulation of tidal effects would be particularly difficult
Effects of industrial wastewater managed separately or blended with municipal wastewaters	x	x	x	x	x	x	Effects vary depending upon type, flow and quality of the industrial waste and the type and size of the wetland area receiving the wastewaters
Need for a pilot-scale facility	x	x	x	x	x	x	Added costs are a disadvantage while advantages are often not tangible
Contingency planning to address extreme weather, spills or treatment failures	x			x		x	

TABLE 7.3-2
ENGINEERING FACTORS PERTINENT TO UTILIZING WETLANDS
FOR SEAFOOD-PROCESSING WASTEWATER MANAGEMENT

Factor (or consideration)	Planning	Design	Installation	Operation	Maintenance	Monitoring	Comments
Extreme variability of wastewater flows and qualities at one location	x	x				x	Those responsible for wetland maintenance and monitoring should keep in communication with seafood products superintendents
Compatibility of wastewater and wetland; need for a pilot-scale study	x	x					The need for a pilot-scale study is considered to be greater for seafood processing wastewaters than for municipal wastewaters which have no significant industrial components.
Selection of treatment processes and required effluent quality	x	x					Regulatory agency involvement is needed that is consistent for each discharger in a particular state
Effects of changes in industrial activities on utilization of wetland for wastewater management	x						Seldom evaluated by discharger

water-table level, seasonal precipitation, runoff and other natural factors.

- Water quality components refer to the constituency of the effluent and to potential changes in water quality parameters following discharge.
- Regulatory control refers to permitting, enforcement of water quality standards and funding. Regulatory requirements may promote or restrict the use of saltwater wetlands for wastewater discharge.

These key factors could affect the vegetation or wildlife within the marsh, public health, or use of the marsh as an alternative for wastewater management.

7.5 STUDY RECOMMENDATIONS

The use of saltwater wetlands for the management of municipal or seafood processing wastewater is an area in which many technical questions remain unanswered. The focus of much of the recent wetland wastewater systems research has been directed more toward freshwater rather than saltwater systems. In recognizing the requirements of saltwater wetlands and the differences between saltwater and freshwater systems, several technical areas have been identified in this report that are appropriate for further study. Areas for further study are grouped into soils/geomorphology, vegetation, hydrology, water quality, wildlife and engineering topics.

7.5.1 Soils/Geomorphology

- . Wetland surface area needed to meet wastewater management objectives;
- . Wastewater loading rates based on uptake of nutrients by soils;
- . Relating estuarine characteristics (river and tidal flows, depositional/erosional patterns, sediment budgets, tidal energy, soil characteristics, etc.) to wastewater discharges;
- . How metals, toxics and pathogens are tied up or released from sediments;
- . How long pathogens remain viable in sediments.

7.5.2 Vegetation

- . Nutrient removal abilities of saltwater wetland vegetation;
- . Effects of freshwater wastewater discharge on saltwater wetland vegetation;
- . Wastewater discharges to mangrove systems;
- . Effects of toxics, metals and pathogens on vegetation.

7.5.3 Hydrology

- . Seasonal hydrological parameters that might affect nutrient flushing;
- . Groundwater flow patterns;
- . Hydraulic loading and loading rates;
- . Relating hydraulic loading in terms of frequency, duration, and water depth to effects on vegetation and animal life, soil saturation, decreased storage capacity, etc.;
- . Discharge velocities to avoid erosion;
- . Effects of discharges on seasonal wet/dry cycles;
- . Effects of continual inundation on oxygen levels in marsh waters and the resultant effects on nutrient availability.

7.5.4 Water Quality

- Long-term ability of saltwater wetlands to assimilate wastewater and the long term effects of wastewater loading on saltwater wetlands;
- The effects of seasonal influences, tidal influences and coastal storms and tidal surges on wetland water quality in wetland wastewater systems;
- Loading rates needed to maintain water quality.

7.5.5 Wildlife

- Impacts on wildlife from wastewater application;
- Impacts on wildlife from freshwater wastewater influences;
- Relating changes in vegetation to effects on wildlife;
- Impacts on wildlife (including shellfish) related to toxic substances, metals, pathogens;
- Food chain effects related to wastewater discharges (including effects of metals, toxins and pathogens).

7.5.6 Engineering

- Design criteria for hydraulic nutrient and organic loading rates to saltwater wetlands;
- Effects of seafood processing wastewater on saltwater wetlands;
- Criteria for establishing detention times or water depths;
- Effects of chlorine or other disinfectants in terms of public health and ecosystem toxicity;
- Distribution systems and schedules;
- Need for back-up systems and storage capacity;
- Downstream monitoring.

8.0 LIST OF PREPARERS

U.S ENVIRONMENTAL PROTECTION AGENCY

Robert B. Howard
Ronald J. Mikulak

Chief, NEPA Compliance Section
Project Officer

APPLIED BIOLOGY, INC. PRIME CONTRACTOR

Nancy W. Walls
Sue A. McCuskey
David J. Herrema
William B. Rhodes
Kenneth J. Stockwell
Christopher Hoberg
Stephen C. Wiedl
Alyse Gardner
Joan Dupont

Project Manager
Project Director
Environmental Scientist
Ecologist
Ecologist
Ecologist
Ecologist
Ecologist
Ecologist

GANNETT FLEMING CORDDRY AND CARPENTER, INC. SUBCONTRACTOR

Thomas M. Rachford
David B. Babcock
Stuart Miner
Lynn Devel-Rezak

Project Manager
Environmental Engineer
Institutional Analyst
Institutional Analyst